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Teaching Professional Attributes

By N. W. DOUGHERTY

Dean of Engineering, University of Tennessee

The word "professional" has been bandied about so much that it has a flood of meanings all the way from a person who makes a living from a special skill to the *noblesse oblige* of the learned practitioner. We tried to get help from the dictionary and, of course, could find nothing that was not very common knowledge:

"The occupation if not purely commercial, mechanical, agricultural, or the like, to which one devotes oneself; a calling in which one professes to have acquired some special knowledge used by way either of instructing, guiding, or advising others or serving them as an art; as, the profession of arms, of teaching, of chemistry."—Webster's New International.

The writer was having quite a time in being specific. As a matter of fact, he could not pin his word down. We will have to define our meaning when we suggest that we teach young engineers to be professional.

As a member of ECPD's Committee on Professional Recognition I have made some study of the meaning as applied to one who is practicing in a field of applied knowledge. After some discussion and exchange of views the Committee published in its 1945 annual report certain attributes which seemed to define professional practice:

"Attributes of a Profession and Its Practitioners [1]

Of a Profession:

1. It must satisfy an indispensable and beneficial social need.
2. Its work must require the exercise of discretion and judgment and not be subject to standardization.
3. It is a type of activity conducted upon a high intellectual plane.
   (a) Its knowledge and skills are not common possessions of the general public; they are the results of tested research and experience and are acquired through a special discipline of education and practice.
   (b) Engineering requires a body of distinctive knowledge (science) and art (skill).

[1] References:

"Report of the Investigation of Engineering Education" by W. E. Wickenden, vol. 2, p. 1107; Annual Report ECPD 1941, page 28.

Vannevar Bush, American Engineering Council, 19th Annual Meeting, 1939.

N. W. Dougherty, *Civil Engineering*, June 1945; JOURNAL OF ENGINEERING EDUCATION, December 1944, June 1945.

Bryne J. Horton, Graduate Faculty of St. John's College.

Robert E. Doherty, JOURNAL OF ENGINEERING EDUCATION, September 1944. Talk delivered at the annual meeting of SPEE, June 1944, Cincinnati, Ohio.

4. It must have group consciousness for the promotion of technical knowledge and professional ideals and for rendering social services.
5. It should have legal status and must require well-formulated standards of admission.

Professional Practitioners:

1. They must have a service motive, sharing their advances in knowledge, guarding their professional integrity and ideals, and tendering gratuitous public service in addition to that engaged by clients.
2. They must recognize their obligations to society and to other practitioners by living up to established and accepted codes of conduct.
3. They must assume relations of confidence and accept individual responsibility.
4. They should be members of professional groups and they should carry their part of the responsibility of advancing professional knowledge, ideals, and practice."

There is probably no need of threshing over the old straw which questions engineering as a qualifying activity. I will assume that it does qualify and permit the reader to furnish the arguments for and against. The reasons are very obvious why we have a wide difference of opinion. Engineering practice ranges over the whole of human activity in construction, production, transportation, communications, valuation, and the development of natural resources. Responsibilities range from artisan to chief engineer or owner and training ranges from "picking it up on the job" to many years of formal scientific and technological attainment. It is not surprising that we have trouble in finding a term which will describe such a heterogeneous group.

As we go into the future it is becoming apparent that there will be a much smaller percentage of engineers without formal training in professional practice and that college training will become more and more the entrance requirement to professional activity. Since students now in college will be the professionals of the next ten and twenty years we should, by taking thought, see if we can add to their professional stature.

Can these things be taught? Here my answer must be in the affirmative. Any principle or practice which can be identified can be taught. But since many of them are intangibles, attitudes, or ways of doing things, we may not be able to use all of the practices of the classroom or the laboratory. I am afraid Rousseau was optimistic when he taught that in a state of nature all of us would be good and that we would exhibit traits of self-denial and that we would work with no thought of the reward. In a profession there must be an eleemosynary element—a refined gracefulness—and a will to do because it is right to do. Such elements and attitudes come from the home, the school and from our selected associates. Too rarely do they come by accident and by the laws of nature.

First of all, to teach any quality the teacher must possess it. The emphasis must be on "being and becoming" and not on "getting and holding." One grows into the stature of a professional rather than by decision changes over into a professional. It is very hard for the charlatan to make himself over into the full grown professional practitioner. The qualities are very deep, certainly more than just skin deep. The practice must be in accord with the declaration.

Probably most of the teaching success will come by contact and contagion

rather than by lecture and assignment, yet there are some things that formal instruction can do. There is an atmosphere and a climate which may be described, an attitude of mind that may be developed and a spirit which may be transmitted.

The teaching of science and applied science requires the application of many of the qualities required of a professional. Strict adherence to the truth, without regard to personal gain or popularity, is essential. This is a quality needed to perform in any of the learned professions. Science teaching requires quantitative thinking; science practice requires it in detail. Professional practice thrives on quantitative abilities.

A few weeks ago I prepared a short paper on the relation of democracy to the development of science in the world. In the study it was apparent that the practice of the learned professions had a similar development. Democracy and science depend upon freedom of the individual; professional attitudes and responsibilities are individual things and must be borne by individuals. We can hardly think of a major professional decision which will not rest upon some individual shoulders. Training in responsibility will be training in professional practice. Professionals must do what they, as professionals, determine should be done. Here again their practice depends upon freedom of the individual. Practices in engineering teaching which tend to destroy individuality should be weeded out and thought should be devoted to methods of developing originality. Routine kills the professional spirit; formalism should only be practiced at its burial.

Certainly we can teach the codes of ethics in the classroom and the laboratory. We can teach the relation of practitioner to client and the responsibility of practitioner to his fellows and to the public. By conscious effort the teacher can point to the responsibilities and practices which lead to professional success. All students should have their attention called to some good book on etiquette, and, from my observation of some grown-ups, they could stand some classroom instruction in it.

There are certain forces which act against professionalism in engineering. One is the fragmentation of the profession. On every side is a multiplicity of organization; unity is practically unknown. Certainly good teaching can develop a cooperative attitude among practitioners and prevent part of the going in many directions. Faculties should study their offerings and avoid multiplication of curricula.

Individuality is a professional requisite but the lone wolf does not add much to professional practice. Students can be taught the art of cooperation and certainly they can be given instruction and practice in the ways of group action. They can learn that the judgment of a group can be much better than the judgment of any individual in the group and that the emotional actions of the group may be much lower than the normal actions of any of its members. The study of science and technology tends to steel the individual against compromise. In these fields there is little need of compromise but in the fields of human relations there is constant need of understanding and respecting the point of view of others. Good teaching can help in this much abused area of professional practice. I have just finished reading Van Doren's "The Great Rehearsal" and it is a good lesson in group activity.

Our professional pride has stood in the way of better public understanding. There seems to be something mysterious about our manufacturing processes which causes engineers and their industries to try to keep trade secrets. Much that each industry knows is better known by its competitor and yet there is a secrecy about the plant which defies understanding. Then, too, we have tried to hide our light under a bushel. Our codes of ethics forbid laudatory advertising and we construe the code to mean no advertising at all. A reasonable attitude may be developed in the classroom and from assignments in the library.

Here are some things that we can do which will strengthen our professional teaching and help build a better engineering profession. First, let us develop some kind of common core of instruction which will be peculiar to engineering. It must be more than the frills of professional attitudes; it must be the real heart of the program. I suggest that teachers of mechanics, fluid mechanics, thermodynamics, physics, electricity and magnetism, drawing, and the other common subjects in the engineering course of study give special emphasis to the fact that these subjects identify students as engineers rather than as civil engineers, hydraulic engineers, radio engineers, power engineers, etc.

Student meetings can be made into forums for unity of action. Instead of always emphasizing the differences between the groups of engineers let us talk about some of the common things—the engineering method, the approach, the attitude, the spirit and the fact that all engineers have the same economic problems. Incidental instruction in the several classrooms may give good dividends along the path of unified action.

Pride in ancestry and hope for posterity have been driving forces in all generations. We have a right to take pride in our past engineering achievement and we have bright hopes for an expanding future. There is no such thing as a mature economy for the inventive mind and the one who knows science and technology. Teachers can develop the traditions of the past and inspire for the future. These will add to the professional abilities of their students.

Finally let us take this gospel to the beginning student. Let him know that he is embarking upon a path of hard work but one which will lead to satisfaction and achievement. If he cannot become enthusiastic about the prospect he will probably falter by the wayside and fail to become professional. A will to do and to become are basic to success in any profession.

"Higher Education for American Democracy"[1]

By WELLER EMBLER

Head, Department of Humanities, The Cooper Union

"Higher Education for American Democracy," the comprehensive report of the President's Commission on Higher Education, will be issued when it is completed in a series of six volumes. Volume I of the series, under the title "Establishing the Goals," is a document of great value for all Americans, and it is, of course, of distinct importance for those whose work is in the field of education. The findings and the recommendations of the President's Commission presented in this initial report reflect the changes in the cultural ideals of twentieth-century Americans, changes which the entire system of higher education must take seriously into account if our democratic way of life is to move ever forward toward its fulfillment.

It is not surprising to learn from this first report that even though it is the tendency of the American people to seek higher education in ever-greater numbers, the educational attainments of the American people are still substantially below what is necessary for effective individual living or for the well-being of our society. Our rapid technological progress is enough in itself to demand that higher education be extended to more people. But in addition it is pointed out in the Preface to the Commission's report that America can no longer remain in its traditional isolationism and that our citizens must have knowledge of other peoples in order to further international cooperation. Moreover, the coming atomic age will bring with it social and economic changes which must be anticipated and prepared for. Are our colleges and universities ready to train ever larger numbers of students and are they ready to assume the new tasks which will be imposed upon them? Progress in the field of expansion has been made, but higher education in America has need of the considerable reviewing which the President's Commission has given it; and our defections in the light of future needs are all too apparent.

If we are to realize democracy more fully and completely, we shall have to educate more people at each level of the educational program. The Commission believes that in 1960 a minimum of 4,600,000 young people should be enrolled in non-profit institutions for education beyond the traditional twelfth grade. This figure would represent about one-half of the college-age population in 1960 and would be an increase of approximately 50 per cent over the normal expectation under a

[1] Higher Education for American Democracy, Volume I, "Establishing the Goals," is the first of six volumes of a report by the President's Commission on Higher Education, 1947. These may be obtained from the U. S. Government Printing Office.

continuation of postwar trends.[2] In order to provide for a doubling of the student load, it will be necessary not only to expand educational facilities but to bring public opinion to an awareness of the "transcendent" importance of education, so that it will support and insist upon the necessary increase in appropriation for higher education.

If we are to realize democracy more fully and completely we shall also have to devise patterns of education that will prepare large numbers of students to accept effectively the responsibilities of modern society. To preserve our democracy it will be necessary, says the Commission, for higher education to put emphasis on the development of the individual, perfecting "the intrinsic powers of every citizen." Development of self-discipline, sensitivity to injustice and inequality, insight into human motives and aspirations, these together with the development of the spirit of democratic compromise and cooperation are aims of democratic education. But it should be remembered also that self-discipline is not enough by itself; and training in social responsibility is essential. "No man can live to himself alone, expecting to benefit from social progress without contributing to it." [Page 10.] The meaning of democracy, the ideals of democracy which have not yet been fully realized, and allegiance to democracy should be learned as fundamental concepts. Without a deep belief in the worth of the individual, the dignity and value of human life, democracy is impossible; without a realistic knowledge of the actual processes by which the political, economic, and social life of the people is carried on, political action is aimless.

It is, however, not enough that we attend solely to our problems at home. "Our thinking still bears marks of provincialism." [Page 16.] And the report of the Commission emphasizes modern man's need to sense the sweep of world history in order to see not only the common humanity of men everywhere but to see "his own civilization in the context of other cultures." [Page 17.] There are rich advantages in cultural diversity, and this is apparent to us in the different cultural backgrounds of the diverse groups which make up America. But it should not be forgotten, of course, that interdependence is as real and as important as individuality. If the cooperative spirit is to function, our colleges and universities will be responsible for training personnel in an understanding of human relations, in understanding of races as well as individuals, and in leadership for the many responsible jobs of modern society. Therefore a program of intercultural understanding for world citizenship should be a part of every person's general education.

In Chapter II of the report, the Commission presents statistical evidence of the barriers to equal opportunity in education. In the section on

[2] In arriving at the enrollment recommended for 1960, the Commission "gave consideration to the results of the Army General Classification Test." The results of this test as given to about 10,000,000 men entering the enlisted Army together with the results of the American Council on Education Psychological Examination as given to entering students by several hundred colleges afforded the evidence for concluding that (1) at least 49 per cent of our population has the mental ability to complete 14 years of schooling with a curriculum of general and vocational studies; and (2) at least 32 per cent of our population has the mental ability to complete an advanced liberal or specialized professional education. [Pages 40–41.]

"Economic Barriers" it is pointed out that the largest families are those with the lowest incomes. Despite the upward trend in average per capita income, millions of capable young people cannot afford a college education, and this is obviously a condition which "is depriving the nation of a vast amount of potential social competence which it sorely needs." [Page 29.] There exist also glaring regional variations in educational opportunity, and "the fact is that the future citizens of the Nation are being born in disproportionately large numbers in communities in which economic resources are the weakest, the plane of living the lowest, cultural conditions the poorest, and the home the least well equipped to contribute either to the physical well-being of youth or to their intellectual development." [Page 31.]

A third barrier to equal opportunity exists in the restricted curriculum. "Many young people have abilities of a different kind, and they cannot receive 'education commensurate with their native capacities' in colleges and universities that recognize only one kind of educable intelligence." [Page 32.] Our society needs an enormous variety of talents. It is essential, therefore, that our colleges provide programs for the development of abilities other than those involved in academic aptitude.

One of the outstanding barriers to equal opportunity is the disadvantage suffered by our Negro citizens. Whereas gains have been made toward eliminating the racial inequalities responsible for the low level of educational achievement by the Negroes, inequalities remain, and it is the opinion of the Commission that where segregation is practiced, it "lessens the quality of education for whites as well. To maintain two school systems side by side . . . means that neither can be of the quality that would be possible if all the available resources were devoted to one system."[3] [Page 34.] And there exists in many colleges and universities, especially in the professional schools, a practice which "is a violation of a major American principle"—the quota system. Under a selective quota system for admission, "the chance to learn, and thereby to become more useful citizens is denied to certain minorities, particularly to Negroes and Jews." [Page 35.]

There are dangerous consequences to inequalities of opportunity, for we need desperately every bit of trained intelligence we can assemble. With this in mind, the Commission recommends that steps be taken to provide high-school education for all normal youth; to make education through the fourteenth grade available in the same way that high-school education is now available; to provide financial assistance to competent students in the tenth through the fourteenth grades who would not be able to continue their education without such assistance; to reverse the present tendency of increas-

[3] At the end of the section entitled "Toward Equalizing Opportunity," the report says: "Educational programs everywhere should be aimed at undermining and eventually eliminating the attitudes that are responsible for discrimination and segregation —at creating instead attitudes that will make education freely available to all." To this recommendation is appended a footnote which reads: "The following Commission members wish to record their dissent from the Commission's pronouncements on 'segregation,' especially as these pronouncements are related to education in the South. Arthur H. Compton, Douglas S. Freeman, Lewis W. Jones, Goodrich C. White. A fuller statement, indicating briefly the basis for this dissent, will appear in Volume II of the Commission's report." [Page 39.]

ing tuition and to aid deserving students through programs of scholarships and fellowships; to expand considerably our program of adult education; to make public education at all levels equally accessible to all, without regard to race, creed, sex, or national origin.

One entire chapter of the report, Chapter III, is devoted to the need for general education. Overspecialization has destroyed the unity of liberal education and the wholeness of adult personality. The civic conscience, too, has suffered as a consequence. The report of the Commission on this subject will be a deep consolation to those forward-looking American educators who have been distressed over the ill effects which a too specialized training has had on the transmission of our common cultural heritage. The Commission points out that the failure to provide an integrated view of human knowledge and human experience is cause for "grave concern," for human beings cannot live rightly and well in a free society without a common core of values and attitudes. General education should, therefore, "embrace ethical values, scientific generalizations, and aesthetic conceptions, as well as an understanding of the purposes and character of the political, economic and social institutions that men have devised." [Page 49.]

The section in Chapter III dealing with the objectives of general education is a thoughtful presentation of the subject and one which all educators will want to read with equal thoughtfullness. It says little we have not heard before in the various reports of university committees on general education, but concentrates the findings of current experience in general education and gives weighty support to the almost universal agreement that mastery of specific information will not equip a human being to live humanely with others or fully with himself.

It is through the study and development of attitudes that ethical principles and civic responsibility become habits of mind. Living understandingly with other people, being emotionally well adjusted, maintaining physical and mental health, enjoying and learning from literature and art, acquiring skill in critical and constructive thinking—these are the benefits to the individual and to society that accrue from a general education.

It should be remembered, however, that general education cannot succeed if emphasis is put on research in special fields, nor if learning is restricted to the classroom. In the expansion of learning, a new definition of scholarship and an imaginative use of extra classroom resources are needed. The new concept of education says simply that general education has a position of equal dignity and importance with vocational and professional education. This new concept means among other things that there exists not only an unwarranted degree of specialization at the underclass level, but that even in the senior college programs of concentration "need to be built around a much wider range of intellectual and occupational objectives to serve a much larger and less selected body of students." [Page 72.]

Considerable attention is given by the Commission to the need for increasing the number and the activities of the community college. The community college, usually controlled and supported under public auspices, should emphasize programs of terminal education of a semiprofessional nature. "For these semiprofessional occupa-

tions a full four years of college training is not necessary. It is estimated that in many fields of work there are *five* jobs requiring two years of college preparation for every *one* that requires four years. Training for these more numerous jobs is the kind the community college should provide." [Page 69.] But the semiprofessional education should not be narrowly technical. It should include a goodly amount of general education for personal and social development. Moreover, in addition to semiprofessional training, the community college could and should serve as a center of learning "for keeping intellectual curiosity alive in out-of-school citizens." To this end the community college should become a center of adult education. In fact, concerning adult education, the Commission recommends that every college and university become a "community college." The need for stimulating in adults a continued zest for learning is only too apparent and is the responsibility of our educational system.

Of particular interest to faculties of engineering schools is the section in Chapter IV which estimates the occupational needs of the nation. Whereas an acute shortage of doctors and nurses is expected by 1960, the recent increase in engineering enrollment "indicates that the supply of engineering graduates may exceed immediately available engineering positions by June 1950, or perhaps 1949, and that if enrollments continue at their present level, this condition might continue in later years." [Page 81.] Fortunately, according to the Commission, engineering education has for some time been recognized as having great value as general education. And this realization has resulted in a "decided trend toward the inclusion of more humanistic and social studies in engineering curricula." [Page 81.] Nevertheless, the possible future surplus of engineering graduates over immediately available engineering positions "emphasizes a continuing need for . . . examination and revision of curricula by the engineering colleges.

"It also emphasizes the imperative need of a thoroughgoing program of guidance and selection of prospective college students, especially prospective engineering students, so that they may understand the requirements of the profession, the employment opportunities in it, and the possibilities of utilizing an engineering education as general education for citizenship and a greater variety of occupational outlets." [Page 81.]

For the most part, the later pages of the Commission's report are given over to an examination of the graduate school. What the Commission says here is of first importance; for many educators have long suspected that "graduate education is in need of thorough revision." The report presents interesting statistics. The total graduate student body has grown from 5,800 in 1900 to 106,073 in 1940, and the number of Ph.D.'s awarded annually has risen from 342 in 1900 to 3,787 in 1947, an over-all increase of about 1,000 per cent. [Page 86.] Moreover, it has been discovered that less than a third of the holders of Ph.D. degrees are primarily engaged in research in government and industry. It is therefore the opinion of the Commission that graduate programs should not be confined to training in proficiency in research. For the fact is that "graduate schools today are engaged primarily in training undergraduate teachers." [Page 87.] Here, therefore, lies a striking inconsistency and severe evidence of cultural lag. For it is in the preparation

of college teachers, says the report, that the graduate-school program is seriously inadequate. The Commission invites a new definition of scholarship which shall "include interpretive ability as well as research ability, skill in synthesis as well as in analysis, achievement in teaching as well as in investigation." [Page 91.] As for research programs in the graduate schools, it would be courting disaster to neglect research in the social sciences, and a large measure of our financial and human resources should be devoted to the social sciences. As for research in the natural sciences, the report recommends that such research be committed largely to the care of the universities. In turn, the universities should concern themselves more with basic research and less with applied science, for in the long run industry is better equipped, and in a sense better qualified, to carry on the application of the scientific findings of basic research. However, the report recognizes that if university research is to be concentrated on basic investigations, "financial assistance in substantial amounts must be provided. Vastly increased public appropriations, both State and Federal, are a necessity." [Page 94.]

At the conclusion of the Commission's report is a short section on "The Social Role of Higher Education." American colleges and universities must envision a much larger role for higher education in the national life. They can no longer consider themselves merely the "instrument for producing an intellectual elite; they must become the means by which every citizen, youth, and adult is enabled and encouraged to carry his education, formal and informal, as far as his native capacities permit." [Page 101.] And this in a serious way is the Commission's final word. The strength of a democracy is measured in terms of the universality of the education of the people; the very lifeblood of democracy is the skill and knowledge necessary for reconciling the differing opinions and interests of the people.

Relative Values in European and American Systems of Engineering Education*

By L. E. GRINTER

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It may appear strange for an American who has never studied in a European university to attempt to compare the results of engineering educational procedures used on the two continents. However, American engineering educators have had an unusual opportunity during the decade of the dictators to observe the strengths and the weaknesses of European educational methods through the medium of those students who have come to the United States to complete their undergraduate education or to enter our graduate schools. We therefore may be able to offer a critical comparison of the relative values of these two systems of engineering education. European teachers have had an even better opportunity to observe American teaching methods by their appointments as teachers in our colleges. It becomes clearer each year that their criticisms and suggestions have gradually been reshaping the American pattern of higher education. Such interchange of ideas and of criticism always results in improvements.

In the limited field of engineering education it is perhaps safe to compare European and American educational objectives without considering the many variations that exist in the two hundred institutions involved. It seems fair to say that European procedures at the university level have had as an objective the education of exceptional students. It also seems fair to say that American universities have directed their principal attention toward the average student. The result is that Europe has hand polished a limited number or, in fact, a small number of engineering scientists while America has mass produced a large number of practical engineers. Fortunately, both continents have had some schools which countered the basic trend, but the emphasis has been as indicated.

It is only necessary to note that about 225,000 baccalaureate students were enrolled in the engineering colleges of the United States in the fall of 1946, while perhaps no more than 5000 were similarly enrolled in England, to understand the results of this great difference in educational philosophy. It is also possible to evaluate the results in terms of differences in industrial production. The older continent has surpassed in fine workman-

* This article was prepared for presentation at the International Congress for Engineering Education at Darmstadt, Germany, by invitation from the Rector of the Technische Hochschule Darmstadt, Professor Dr. Richard Vieweg.

ship; the newer in volume production. We now realize that America has depended to an unwise extent upon scientific ideas from Europe while Europe has with equal lack of vision been slow to accept the American invention of mass production. Each must adopt certain features of the educational plan of the other if each is to progress as it should.

In the United States there is great need for deeper educational opportunities for exceptional engineering students. The principal weakness of our educational program in the universities stems from the philosophy of mass education at the high school level. Since public education must consider the average student rather than the exceptional student, our university system of education has naturally granted opportunities to the resulting large numbers of high school graduates. Such numbers preclude the possibility of special attention to the unique educational problems of the exceptional student. It remains for those colleges of engineering under private control to lead the way in providing exceptional students with a more scientific education in the engineering field leading to a career in research and the scientific phases of design or in teaching. We have the graduate schools where such studies may be conducted at the post-graduate level, but it is equally important that there be early stimulation of the gifted student in his undergraduate program. It is self-evident that our present group of 225,000 engineering students cannot all be profitably trained for the more scientific accomplishments. Hence two paths of engineering education will be required in place of the single path or curriculum that exists in America today.

In Europe students have always been treated as mature individuals who were expected to understand the necessity for unguided study. Exceptional students react favorably to such instruction, but more direct guidance is necessary for students of average ability. We know this to be true because European teachers in America have been somewhat unsuccessful during their first years of teaching in obtaining good results with American students. After a period of experience in an American university the European teacher learns to assign problems to be turned in for grading and otherwise to set tasks which those students who are not exceptional will perform as essential to an understanding of the subject matter of the course.

If Europe is to reconstruct itself and rebuild its leadership of the past, it will be forced to train engineers in much larger numbers than heretofore. The scientific developments of the war years and those that are now reaching the production stage in industry require large numbers of scientists, engineers and technicians for construction, production and maintenance in addition to those needed for research and design. We realize that Europe has not depended upon schools of engineering for all of its technical personnel. Fortunately there have been more and better technician training schools in Europe than in America; also, apprenticeship training has been effective. However, there are jobs for a much larger number of real engineers than can ever be supplied from the limited number of young men (and women) who are in the exceptional group. And it seems doubtful that technicians trained in a two-year or three-year period can serve as an adequate substitute. Our experience with

shortened periods of training during the war years does not recommend that procedure as universal. In our opinion in America a rather large number of young men of only average ability (for university students) are needed with full four-year engineering training. It will apparently require considerable change in the program of European higher education before this need can be fulfilled.

As a contribution to the usefulness of young engineers who are expected to hold positions in construction, production, operation and maintenance rather than research and the higher phases of design, European institutions will need to place greater emphasis upon laboratory and practical design courses. We have observed that European students who come to America are commonly proficient in the use of mathematics but deficient in skill in the handling of laboratory equipment. If this interest in the theoretical side of engineering education is as common in those students who remain in Europe as in those who have migrated to America, it is clear that there must be dark bands in the spectrum of European education corresponding to the fields of laboratory and pilot plant experimentation and practical design studies. It will therefore be necessary to expand laboratory facilities and, of course, to modernize all educational laboratories in step with recent technological advances. However, much equipment in American institutions is far from modern but when revised to demonstrate modern usages it remains serviceable.

The writer's visit to European educational institutions in 1946 confirmed the natural assumption that European education like American education is due to undergo major changes in the reconstruction period. Everywhere our youth are demanding the opportunity of higher education, and nothing is more certain than that youth in this regard will have to be served. In England the question of whether Cambridge and Oxford Universities should accept larger numbers of students was reaching the stage of national discussion in the summer of 1946. The mere fact that the matter was on the front page of London newspapers for several days is an indication that the issue was considered no minor one.

It is at least fortunate that the demand of youth for a university education in the technical field coincides with the cry of industry for more and more engineers. Perhaps we shall prove again the experience of past decades that more engineers always produce more jobs for engineers. Is it not possible that the number of persons of engineering training that can be used economically by industry may eventually reach or perhaps exceed the number of persons whose interests and abilities make them proper recipients of education in this field.

It has seemed clear for some years that we are never likely to stimulate as many persons to surmount the difficulties involved in achieving the level of the doctorate in engineering as industry and education would desire. Perhaps we shall find that the same situation exists at the level of the first baccalaureate degree in the engineering field. It would be comforting to know that our visions of overproduction of engineers were merely phantoms. At least in Europe there can be no probability of overproduction of engineers until reconstruction and

the natural expansion occasioned by adoption of new technical ideas has reached its peak a decade from now. If national economics can match technical accomplishments, no waning of industrial activity need occur. When we consider the engineering aptitudes of mathematical ability, visual perspective, a practical sense of values and capacity for making decisions, it seems clear that the world as a whole is not likely soon to be over-supplied with engineering leaders, nor perhaps with followers either.

Chemical Engineering Summer School—University of Wisconsin

The CHEMICAL ENGINEERING DIVISION of the A.S.E.E. will hold a summer school for teachers of chemical engineering at the University of Wisconsin, Sunday, August 29, 1948 (arrival date) to Saturday noon, September 4, 1948 (departure date).

The general theme of the meeting will be "What Should We Teach and How Can We Teach It?" Sessions will be devoted to Unit Processes, Report Writing, Thermodynamics, Applied Electrochemistry, Mathematics in Chemical Engineering, Chemical Reaction Kinetics, Instrumentation, The Graduate Program in Chemical Engineering, Teacher Qualifications and Development, the Newer Unit Operations, Plastics Technology, Laboratory Instruction in Chemical Engineering.

The technical sessions will operate 8:30 to Noon and 1:30–3 P.M. This will allow an excellent opportunity for all to engage in recreational activities. Facilities are available for soft ball, tennis, golf, boating, fishing, hiking, etc. A summer school picnic and a banquet with S. D. Kirkpatrick, Editor of Chemical Engineering, as the principal speaker have been arranged.

Lake-front housing at the dormitories has been obtained. Room and board rates are such that it is possible for families to spend the week in Madison at modest cost.

Detailed programs and announcements for the Summer School are being mailed to 550 full time teachers of chemical engineering. Anyone not receiving such a program may secure one by addressing R. A. Ragatz, Chemical Engineering Building, University of Wisconsin, Madison, Wisconsin. Attendance is not restricted to members of ASEE, nor is attendance restricted to members of the teaching profession. Anyone interested in chemical engineering education is welcome to attend.

Growth of the Humanistic Stem

By PAUL FATOUT

Department of English, Purdue University

What has been labeled the "Humanistic-Social Stem" of Engineering Education is of late growth following years of germination that began at least as far back as the earliest days of the ASEE (then SPEE). The story of the dark ages before that is buried in mystery and the dust of ancient catalogues. When the Society's JOURNAL came into being almost forty years ago as a sounding board for academic notions, unorthodox murmurings faintly suggested more liberal engineering education. Musty delving dredges up such sporadic comments as that of a Dean of Applied Science who in 1914 recommended for engineering students:

> thorough drill in the . . . mother tongue, enough . . . foreign language so that the graduate can use it with reasonable facility, actual American and foreign government, honest business methods and the holy principles of friendship, morality, and brotherly love; all these to the end that the graduate may plan wisely, build well and be able to distinguish between legitimate profit and gross imposition.[1]

However, such advanced thinking was rare in 1914.

In 1918 a Joint Committee on Engineering Education, recognizing the need of humanistic studies, cited Professor Aydelotte's liberal curriculum at M. I. T. The committee report, minus specific recommendations, could readily be accepted with that comfortable reservation "in principle," yet allow everybody to jog along about as usual. No evidence indicates any widespread overhauling of engineering programs at that time.

The middle twenties blew up a sudden bustle over written English, on which engineering brethren are substantially in agreement with English departments. Engineers seem unanimously in favor of composition, though they were then—and doubtless still are—divided on familiar and trivial issues: *i.e.*, composition courses designed for engineers vs. general courses; English instructors trained in engineering vs. English instructors trained in English. The record yields much entertaining folklore about that custom-built mechanism, the engineering student, and that engaging but elusive entity, "the engineering mind," supposed to require some precious nourishment more carefully strained than the intellectual food good enough for other brains. These matters, thoroughly aired in the nineteen twenties, are more or less still with us, and echoes rebound from time to time. At any rate, some form of written English has so long been an undisputed part of the engineer's curriculum that it need not be discussed, especially since ele-

[1] William G. Raymond. "Four vs. Five Years for the Engineering Course," JOURNAL OF ENGINEERING EDUCATION, May, 1914.

mentary composition is not considered a legitimate off-shoot of the humanistic stem.

In the 1930's the stem made considerable growth in theory and some in fact. More liberal education for engineers was advocated by Dr. Karl Compton, W. E. Wickenden, and other distinguished technologists more frequently and more articulately than before. They argued for the humanities as aids to the development of the whole man, who should be oriented not only to technology, but also to society at large. In the 1930's the JOURNAL gave increasing space to that thesis in numerous expositions of the view that the engineer is not merely a technologist but a human being in a complex world, where not all problems yield to formula and slide rule.

That was an important discovery, significant in that it was made by the engineering profession. Leaders in the campaign to humanize engineering education were themselves engineers, who freely pointed out the woeful ignorance of technical graduates compared to those of other professions, and who implied that a one-sided technologist is an inadequate person—similar, no doubt, to the most narrow and desiccated Ph.D. in English. One practical result of the growing rumpus was the establishment, about 1938, of the Carnegie Social Relations Program, of which more later.

Thus some twenty-five years or more of painful soul-searching preceded the report, in 1940, of Dean Hammond's Committee on Aims and Scope of Engineering Education. More thorough and specific than any previous effort, that report is the basis for subsequent revision of engineering programs; it is the lever that has pried loose a good many academic crustaceans, who may have let go reluctantly, but who have nevertheless let go. The committee stood on a platform of "science, of humanities, and of social relationships rather than on the practical techniques of particular occupations or industries," stressed "the parallel development of the *scientific-technological* and the *humanistic-social* sequences," and favored "an integrated program of study extending through the entire undergraduate period." [2] For humanistic studies it laid down a six-point program of objectives, surely now sufficiently well known not to require repetition here. The committee also pointed out that a goodly proportion of engineering students never become engineers in the best sense, and that the minority of true professionals should take five years or more of study instead of the usual four. Such comprehensive and revolutionary proposals were not received without rumblings of dissent; nevertheless the report was accepted at the annual meeting of the SPEE in June, 1940.

Endorsing a report is not too difficult; putting it into action is much tougher. Have those thoughtful recommendations remained merely another assortment of pious hopes, or have they caused any actual shaking up of engineering education? Briefly, the surprising answer is that apparently they have shaken. Not enough to loosen anybody's teeth, yet seismographic tremors have undeniably rippled through the granite of curricular strata.

The evidence, still blurry and not all in, may not be clear or complete for some time, as some schools, Purdue

[2] "Report of a Committee on Aims and Scope of Engineering Curricula," JOURNAL OF ENGINEERING EDUCATION, Vol. 30, No. 7, March, 1940.

for example, are only now weathering a change. The signs are that bringing to life a new plan, though agreeable to some people, produces in others as much wrenching and groaning and wear and tear as the birth of quadruplets. No one need suppose that all engineering faculties promptly and eagerly scrambled aboard the Hammond Committee's platform. Some of our colleagues continue to ignore it, and some, I fear, are up there only after being hauled aboard kicking and screaming. Being academic and human, an engineering administrator may not be happy over giving up a technical course in favor of literature or history or sociology; sometimes his anguished howls are all but audible. Hence evolution is slow, and occasionally hedged with shenanigans by which such courses as elementary composition, cost accounting, and naval ordnance are slipped in to prove that old Bilgewater U. has liberalized its engineering curriculum. Yet none of that need upset anybody, or damp his faith in the possibility of change.

When the war brought academic speedups and concentration on specialized technology, the growth of the humanistic stem was for a time slowed down, if not stopped; however, emergency measures seemed clearly not indicative of permanent policy. In fact, according to a survey by E. S. Burdell in 1943, some institutions retained their normal curricula during the war. To discover the effects of the 1940 report, he polled 75 engineering colleges, and received replies from 39. Of these, ten implied positive effect shown by reorganizing the humanistic program, widening choice of electives, increasing hours of freshman English, and adding courses in the humanities. Six others replied that as liberal programs were already in operation there, the Hammond report served as endorsement of their curricula. Hence sixteen institutions, or about one-eighth of all the engineering colleges in the United States, reported being favorably affected.[3] A small minority, yet, allowing for the usual wishful thinking in filling out questionnaires, not too bad a percentage.

In 1944 another SPEE committee, again headed by Dean Hammond, submitted a report on Engineering Education After the War. Reviewing and reaffirming the 1940 report, the committee elaborated upon it by recommending a designated sequence of humanistic-social courses through the four undergraduate years, requiring approximately 20 per cent of the student's time. Specific subjects mentioned were history, economics, government, literature, philosophy, psychology, and fine arts. Underlining a strong restatement of the liberal platform, W. E. Wickenden said:

> . . . it is now time to put up or shut up —to give the humanities and social studies the time, the leadership, the manpower, the content and the financial support that will put them on a level in prestige and excellence with our scientific disciplines.[4]

Since then the JOURNAL has briskly plugged the subject of the humanities for engineers in many articles, mostly in favor, though not unanimously. As recently as March, 1946, S. F. Borg,

[3] E. S. Burdell. "The Humanistic-Social Studies in Engineering Education, Factors and Influences at Work," JOURNAL OF ENGINEERING EDUCATION, Vol. 33, No. 10, June, 1943.

[4] "Report of the Committee on Engineering Education After the War," JOURNAL OF ENGINEERING EDUCATION, Vol. 35, No. 1, September, 1944.

of the Naval Academy, strongly advocated engineering courses only, maintaining that the student interested in the humanities will seek them anyway, either in college or later on. Perhaps that view has a good many ardent, if silent, supporters.

How, then, do matters stand now? The most recent survey was reported in December, 1946, by Lisle A. Rose, who found that proportion of humanistic-social courses in the engineering curricula of 100 institutions ranged from zero in two schools to 20 per cent or more in 13, the bulk (51) reporting 10 to 20 per cent.[5] Proportion is of itself, however, not too important. One may agree with Messrs. Boarts and Hodges (January, 1946), who dilate upon the mystic number 20, and remark that borderline courses are occasionally included to boost the percentage toward that sanctified figure. They say sensibly:

> There is no magic in any predetermined allotment of time for the humanistic-social activity. The objectives set by each school and the means available will dictate inexorably what is needed to achieve the program sought. . . .[6]

At the present time the best integrated humanistic programs appear to be those of M. I. T., Carnegie, Cooper Union, Case, and California Tech. In all five the undergraduate takes at least one humanities course every term, the first year in each being given over to English composition. Thereafter, at M. I. T., for example, the student takes in the second year the U. S. in World History; the third year economic principles the first term, a choice of psychology, labor relations, and industrial economics the second; the fourth year one of four options: History of Science and Thought, Fine Arts, Introduction to Literature, and Industrial Relations.

California puts less stress on economics, more on history and literature. The fourth year student is offered a wide choice of electives, some eighteen courses: Philosophy, Ethics, Sociology, Psychology, as well as various kinds of history and literature—the most extensive array of liberal courses offered by any engineering college in this country. Possibly only in golden California, where everything is lush, could a technical institution maintain the necessary staff. The program is no bluff either; it is administered by qualified authorities drawn from such centers of scholarship as the Huntington Library.

The Carnegie Social Relations Program is a closely articulated curriculum based, according to its Director, on the premise that

> professional education for engineers should develop awareness of problems of social relations . . . the capacity of outlining and analyzing such problems with more than usual clarity of insight, and . . . the ability to propose objective, rational solutions to such problems.[7]

Hence social content with technological implications is apparent in such courses as Origins and Development of the Technological Age, Economic

[5] Lisle A. Rose. "Summary of Information Concerning Humanistic-Social Courses in Engineering Colleges," JOURNAL OF ENGINEERING EDUCATION, Vol. 37, No. 4, December, 1946.

[6] Robert M. Boarts and John C. Hodges, "The Characteristics of the Humanistic-Social Studies in Engineering Education," JOURNAL OF ENGINEERING EDUCATION, Vol. 36, No. 5, January, 1946.

[7] Glen U. Cleeton, "The Carnegie Social Relations Program," JOURNAL OF ENGINEERING EDUCATION, Vol. 35, No. 2, October, 1944.

Analysis of Social Problems, and so on. At Cooper Union the emphasis is also upon social studies in courses like History of Man, and Social Philosophy. The Case curriculum is the most conventional of the five: writing and speaking, Types of Literature, Technical Exposition, and in the fourth year two electives chosen from ten courses concerning literature, economics, government, and public speaking.

Since the curricula of these five institutions range from the elaboration of California Tech to the comparative simplicity of Case, they show what any college can do, if it wants to, with the means available. At Purdue a new plan was launched in the fall of 1946, following recommendations of a Committee on Non-Technical Electives—five engineers, one psychologist, one economist, and one English instructor—which proposed that "hours allocated to non-technical courses in each of the various engineering curricula be thirty where and when possible and not less than twenty-four."

Of the minimum, twelve were already in the schedule: six in composition, three in speech, and three in literature. The additional twelve are accounted for by one course each in history, government, economics, and a new course in psychology tailor made for engineers. To bring his total to thirty, a student may elect freely, subject to his head's approval. However, the committee recommended that "Naval Science and Tactics, Advanced ROTC . . . Mathematics, Physics, Chemistry, etc. . . . not . . . be considered as nontechnical courses since they do not satisfy the objectives of this program."

A typical four-year schedule might be: 1st semester, composition; 2d, speech; 3d, a choice of Modern Fiction, Drama, Essay, Great Books, and English Literature; 4th, composition; 5th, Economics; 6th, either U. S. or European History; 7th, National Government or World Politics; 8th, Psychology. As no plan is ever so simple in operation as it looks on paper, this one has bugs in it. Although allowing choice among "required electives," it is not well integrated, the committee recommending only that "Non-technical courses be distributed as uniformly as possible throughout the eight semesters." Schedules are so tight that only the civil and mechanical engineers have so far provided for the maximum of thirty hours, both by the handsome gesture of dropping some hours of technical requirements. Nevertheless, all schools have agreed to twenty-four, a commendable number. The system has not been born without storm and stress, and if credits in chemistry, ROTC, and Naval Science are totted up as nontechnical electives, no one need be surprised; however, the important fact is that a change has occurred.

Thus convincing evidence proves that engineering curricula have undergone much face-lifting during the past ten years. Whether attitudes have also changed is less certain. To assume a universal metamorphosis of the technological spirit is probably unwise. Among engineers the lineup is perhaps about the same: at one end enthusiastic support for the humanities, at the other a formidable bloc prepared to resist till hell freezes hard enough to defy an atom bomb. However, since human beings can be conditioned to almost anything, a new generation of students and professors may accept willingly what now seems painful to some. Such acceptance may not bring the millennium. Yet on the side of the humanities is

the plausible argument that almost one hundred years of intensifying concentration on and faith in technology alone have somehow not brought the millennium either.

As a substitute we have a perfection of techniques, a multiplicity of things, and a naive belief that the world is prey to no ills that cannot be cured by bigger and better cars and planes, more miles of concrete, more radios, gadgets, nervous breakdowns, and heart failures. That belief has been gathering power ever since the mid-Victorians rhapsodized over the steam engine as the harbinger of the Good Life. To date, the end product of this philosophy is a state of disorder that leaves the reflective observer numb. The thoughtful may conclude that techniques and things are not enough, that no one group knows all the answers—no, not the engineers, the chemists, the physicists, or the English professors—and that applied science does not of itself lead to salvation. D. H. Lawrence remarks upon "the non-vital universe of forces and mechanistic order," leading to "the long slow death of the human being." Apparently some technologists are uneasily aware of a grain of truth in that shocking heresy. That the humanities might rediscover the human being, and assist in curing the ills of the world is not certain, though possible. The least one can say is that they could scarcely do worse; they might contribute some useful observations—if technologists, chemists, philosophers, historians, and other thinkers were smart enough to pool their thinking.

Sections

The spring meeting of the Missouri Section of the American Society for Engineering Education was held at Columbia, Missouri, on April 10, 1948, with the University of Missouri as host. At the morning meeting, S. H. Van Wambeck of Washington University presided. The program included Harry A. Curtis, Dean of the University of Missouri, Curtis L. Wilson, Dean of the Missouri School of Mines and Metallurgy, A. S. Langsdorf, Dean of Washington University and L. E. Stout of Washington University. A short business meeting followed, and the remainder of the morning was occupied by an informal discussion on curriculum content. Particular reference was paid during this discussion to the courses in physics and mathematics taken by engineering students.

The afternoon program consisted of group conferences by the divisions of Chemical, Civil, Electrical, and Mechanical Engineering, as well as Engineering Drawing, Humanities and English, Mathematics, and Physics.

At the evening dinner meeting, George E. Mylonas of Washington University presented an interesting and informative talk on 'The Balkans.'

New officers were elected as follows:

Chairman, Curtis L. Wilson, Dean, Missouri School of Mines and Metallurgy.

Vice-chairman, Ralph L. Scorah, University of Missouri.

Secretary, John W. Hubler, Washington University.

Building an Enduring Civilization

By CARL A. NORMAN

Professor of Machine Design, The Ohio State University

This paper is intended as an attempt to apply engineering thinking to the greatest of all human problems: The building of an enduring civilization. It begins with an examination of the ability of technology, science, philosophy, art and literature to give endurance strength to a civilization, and arrives at a negative attitude. If there is anything that gives spiritual vigor and survival power to a human group it appears to be a simple and fully accepted religion. At least, such religion, or religiosity, has been characteristic of human groups, or movements, which infused new life into disintegrating civilizations.

The rise of this nation was closely connected with a wave of such spiritual invigoration; and there is every reason to try to maintain among our people the faith that actuated the founding fathers and many of our great leaders since.

Ever since the first world war there has been a growing realization among engineers that their work could be as easily destructive as constructive, and that technical skill unconnected with human understanding and wisdom might be a blind and dangerous force.

From 1923 to 1929 The Society for the Promotion of Engineering Education, now the American Society for Engineering Education, under the direction of Dr. W. E. Wickenden, conducted a critical survey of technical education here and abroad. Following this survey the demand for a humanization of engineering training grew more insistent and a number of engineering schools have now introduced curricula extending into the non-technical field.

Hardly had this occurred, however, before studies of modern higher education at Harvard, Chicago, and other universities began to cast some doubt on the quality and human worth also of so-called humanistic education at the present time. It was emphasized by President H. S. Rogers of the Brooklyn Polytechnic Institute and others that, unless such education was fused into a philosophy of life and a dominant worthwhile purpose, it was of questionable social and general human value. Dean A. A. Potter of Purdue University pointed out that some of the most dastardly leaders of the Nazis, preeminently Goebbels, were men of advanced and comprehensive humanistic education.

From the engineering point of view the question to be settled seems to be this: What factors have been important in sound human development and civilization? Hence, what elements in human character and education must we try to develop in order that the race may endure and progress?

Wherever we look in the ruins and records of the past we never find that even great technical and scientific achievement saved civilizations and

nations from collapse and disappearance. This holds true at the Angkor Vat in Cambodia as much as it does at Babylon, Nineveh, and Persepolis, Baalbek, and on through Greece or Rome clear across the Atlantic to the Maya ruins in Yucatan.

Around the year one the Roman writer Vitruvius, in his book on architecture, gave as complete a list as he could of technical achievements and contrivances of his day. It is an astonishing array, most impressive. Up to that time, or but little later, there had appeared such shining geniuses in science and engineering as Euclid, Archimedes, Hero Alexandrinus, and Ptolemy, together with the great builders of temples and palaces, fortresses, siege engines and aqueducts. There seemed to be enough accumulated achievement and originating genius to march the world straight into an era of dazzling mechanical and structural civilization. Instead of that the Graeco-Roman world moved down into the abyss.

But if technical achievement does not save civilizations, neither does philosophy, nor art, seem to do so. The great Greek philosophers Socrates, Plato, and Aristotle appear as their world has passed the zenith of its power, and they cannot stop the decline. Increasingly philosophy recognizes its impotence. It moves into stoicism, a philosophy of fatalism and resignation; into epicureanism, a philosophy of rationed pleasure seeking in a chaotic world; into cynicism and skepticism, distrust of all human intellectual endeavor. When a stoic philosopher, Marcus Aurelius, reaches the imperial purple, this is not the beginning of an era of wellbeing and greatness. It is the end.

The same sort of picture is presented by Greek and Hellenistic art and drama. The period during which the Greeks hurled back the Persians and established their political greatness was a period of archaic and naïve art, mostly of a religious character. The Periclean period of greatest political power coincides with the art of Phidias, still religious in character and most impressive. Even greater technical perfection is however perhaps reached in Praxiteles and Scopas; but their art is perfectly humanized, beautiful, but not inspirational. This development comes during the decline. Human movement and passion are shown with perfection even after Greece has lost its independence; but now even beauty is often lacking. Caricature appears.

And as art develops so does drama and poetry. From the naïve and concrete religious imagery of Homer we come to Aeschylus, the stern dramatist of religion; to Sophocles, humanizing, but at the same time beautifying the religious personalities; to Euripides, interested merely in human destinies and passions; finally to Aristophanes, simply ridiculing the foibles and weaknesses of his age.

Match this development with the political events: Aeschylus, fighter in the great battles that hurled back the Persians and lifted Greece to independence and greatness; Sophocles, a celebrant of the final victory and the greatness that ensued; Euripides and Aristophanes working during the decline and hardly doing anything to stop it. The sculptural series is an exact parallel.

It is hard to escape the conclusion voiced by Professor C. N. Cochrane of the University of Toronto: That the Greek and Graeco-Roman decline was fundamentally caused by a spiritual and

moral disintegration.* A naïve and strong religiosity characterized the people that fought their way into power. Decline set in, political as well as economic, as this spiritual vigor petered out.

If this were a development characterizing only the Graeco-Roman civilization, we should hesitate to apply it to other conditions. It seems, however, to be the historical trend among practically all the civilizations which contributed to the rise of ours. That eminent orientalist, Dr. James Henry Breasted, Director of the Oriental Institute of the University of Chicago, has written a most authoritative "History of Ancient Times." He depicts the course of the history of those Semitic nations that rose to greatness in the Mesopotamian Valley—the Babylonians, the Assyrians, the Chaldeans—as a reiterated irruption into the valley of desert tribes with a strong and simple shepherd religion. He characterizes Jewish prophecy as a survival of the spirit of this simple and vigorous faith in the period of more corrupt and degenerate religion and morality of town and agricultural life as it developed.

Of great interest is also that the last great wave of Semitic incursion which so profoundly affected our rising civilization during the medieval ages, that of Mohammedanism, began likewise as a religious wave of great simplicity emerging from the desert. But the general pattern holds true not only of the Semites. It holds just as true of the Aryan group to which most of us belong.

When the Persians break out of their mountain fastnesses and conquer the Ionian and the Mesopotamian world they are profoundly actuated by the stern and vigorous religion of Zarathustra. The Germanic tribes that appear from the northern woods or the South Russian steppes and break down the Roman Empire are stongly enlivened by a religion that puts manly deed above all other virtues. The same thing holds true of the Viking incursions which so profoundly harassed medieval Europe, but also injected ethnic elements of great vigor into the new nations emerging at that time, and in several instances gave them their ruling houses.

Let us draw the conclusion tentatively that a simple and vigorous religious belief has been an important characteristic of human groups in the heyday of their vigor and striking power. And let us on this basis inquire into the development of the modern world and later into the situation in which we now find ourselves and what we are to do about it. We are aware that many other interpretations have been made and are possible. But the interpretation from the religious angle seems to be of the greatest importance just now since the most dangerous antagonist with whom we have to contend is a power ruled by a group of atheists who try to extirpate religion from among their followers.

Many authors have taken the attitude that the modern world had its begining in the thirteenth century. That this should be true of Catholic writers like J. J. Walsh is no wonder, since admittedly the power of the pope and the Catholic church had risen to an absolute maximum under Pope Innocent III who reigned from 1198 to 1216; and since Catholic thinking in that century found its most outstanding expositor in Thomas Aquinas. But even non-catholic, or non-religious writers have to admit the immense im-

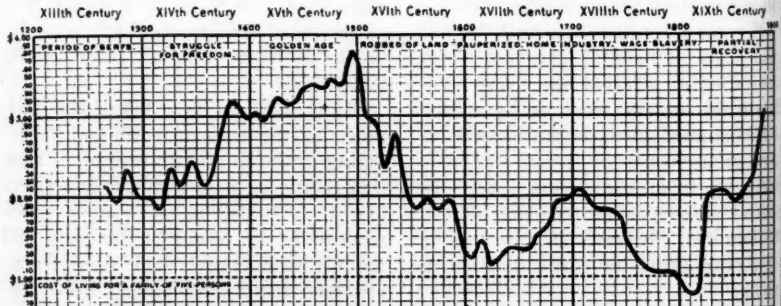
*See *Christianity and Classical Culture*, p. 157.

portance of that century as a birth-point of modern civilization. Scientifically the thirteenth century was the century of Roger Bacon, the first philosopher to demand that scientific thought should be carried back to original sources of information; it was the century of the development of modern clock mechanism and the general introduction of modern time reckoning; it also saw the general adoption of the Arabic or decimal system of numerals. Politically the thirteenth century, as Professor Edward P. Cheney points out, saw vigorous beginnings of popular self-government and parliamentary institutions,* not only in England, but in many other European countries, including Spain.

Of most interest for engineers is probably, however, that the thirteenth century was the real starting point of the vigorous development of the medieval guild system. This system was a serious, and to begin with, in the writer's opinion, a highly successful attempt to apply Christian principles to production and trade. The three fundamental guild rules were those of *fair price, fair wage,* and *fair quality of goods.* The observance of these rules was secured only to a subordinate extent by government action. It was the guilds themselves that enforced them; and guilds were organizations of master tradesmen, whose skill and competence were guaranteed by a vigorous apprenticeship. The guilds were strongly penetrated by the religious spirit. Each guild had its patron Saint. And strong rules of mutual assistance and charity were observed no less than freedom of enterprise.

The general wellbeing that resulted to artisans from the successful application of this system is best shown by the graph in Fig. 1 of the real income of an English carpenter in the thirteenth, fourteenth and fifteenth centuries. It is taken from authentic data in Rogers' and Bliss' great work *Six Centuries of Work and Wages,* data derived from the examination of still extant bills for goods and services in

* Cheney, E. P., *The Dawn of a New Era, 1250–1453.*



Wage Condition of the English Carpenter in Proportion to the Cost of Living for a Family of Five Persons, Calculated for Every Decade from 1260 to 1887.

FIG. 1. From Rogers and Bliss, *Six Centuries of Work and Wages.*

medieval times. The well-being rises steadily from the thirteenth through the fifteenth century. Collapse sets in at the time of the great geographical discoveries when unparalleled opportunities for adventure and enrichment drew the bold and daring away from accepted standards; and the church at the same time had become utterly worldly, greedy, and demoralized.

It has become customary for modern people to glorify the time of the Renaissance because of its scientific and artistic achievements. It is forgotten that this period was one of complete political, economic and moral chaos in the homeland of the movement, Italy; that political independence, popular government, and economic life were trampled under foot by princes and hired soldiers; that murder, rapine, and wars for revenge were rampant; and that the political philosophy of the day was that systematized by Niccolo Machiavelli, who declared that craving for power and lust for gain are natural instincts in mankind, and are the motives on which he should act who wishes to dominate men.* Now the thirteenth century, as the art and architecture of the day so clearly show us, was a period of strong and childlike Christian faith. Through the following centuries, as sophistication and secularization increased, a decline gradually set in and all the magnificent art and scientific developments of the Renaissance could not stave off final debacle in Italy.

However, in the rest of Europe two different currents set in. An increasing frivolization and secularization particularly in France led to developments which ended in the French Revolution. Economically, as the chart in Fig. 1 shows, the greatest depth of misery for the common man was reached in England during the forty years following 1776, in which year there was published Adam Smith's *Wealth of Nations;* a book in which the Machiavellian attitude was taken that only self-interest is an ever present motivation, and that therefore economic life and economic policy should be based on that motive.†

Fortunately for the world another line of development had also taken place. A new wave of religious intensity had broken forth in Germany and Switzerland, in the form of the protestant reformation. The wave spread into England and Scandinavia. In time this wave sent to America groups of emigrants of great spiritual vigor and intensity, and here on this continent was founded a new empire imbued with passion for human freedom and for neighborly cooperation. Colonies were planted all along the Atlantic Seaboard and in 1776 these Colonies arose and declared that the time had come when they should "assume among the powers of the earth the separate and equal station to which the Laws of Nature and Nature's God entitled them," and that they did so "with firm reliance on the protection of Divine Providence."

Never did such reliance on Divine Providence prove more fully justified. Almost all the great powers of earth came in some way or other to the assistance of the rebelling nation. In fact, in the last decisive battle at Yorktown there were, according to Dean C. F. Wittke, more French soldiery engaged than American. Later Napoleon, the great law grabber, sold to the young republic for a mere 15 million dollars a land area out of which

* Niccolo Machiavelli, *The Prince.*

† Rogers and Bliss, *Six Centuries of Work and Wages,* p. 144.

were subsequently formed in whole or in part some thirteen states. A war with Mexico, none too bloody, extended the empire all the way to the Pacific Ocean; and Russia, whose land hunger now so worries us, sold to us Alaska in 1867 for 7,200,000 dollars gold. In human lives, according to Dean Wittke, the acquisition of our territory had cost us but 19,200 lives—just about half the number we now kill every year in automobile accidents. True, holding together the territory cost us much more blood than that, perhaps a just punishment for not taking seriously in time the solution of the slavery question, which other nations had solved peaceably.

Truly, this nation has every reason indeed to see in sound religion, in reliance on the doctrine that right makes might, the key to future security and prosperity. If it does its duty in the world as the protector of the weak, as the upholder of freedom, it will find itself helped by that Providence upon which the founding fathers relied. If it does not, it will pass out as so many other civilizations have passed out when they strove for riches and pleasure, but lost the religious basis for the fortitude of the soul.

The Role of Mathematics in the Teaching of an Engineer*

By GEORGE C. VEDOVA

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This paper constitutes a brief exposition of the views held by the members of the Department of Mathematics of the Newark Engineering College as to the role that mathematics plays, or should play, in the training of an engineer. These views have been arrived at after consultations by the senior members of the department among themselves, followed by discussions before and by the whole membership of the Department. They are believed to embody the principal aims of the department as it functions at present.

These views have been submitted to the administration of the college and to the chairmen of the various engineering departments, for the purpose of finding out to what extent they are in accord with the over-all aims and policies of the college and what revisions, if any, might be deemed advisable. It is gratifying to be able to report that, to date, no adverse comments have been made and no revisions have been suggested to the department.

This department recognizes four principal aspects of mathematics each of which, it believes, is of value to the prospective engineer, and each of which should be brought to his attention while in training at this college, though not all with the same emphasis. These aspects may be called the technical, the utilitarian, the logical, and the cultural, enumerated here in decreasing order of the emphasis they should receive though, in what follows, it has been found convenient to deal with them in the reverse order.

Cultural Role

Mathematics has long been looked upon as the key to understanding. It was held—and it is contended here that it was rightly held—that a mathematical training is indispensable to any who would acquire basic and real knowledge of the world, whether of the physical world, the living world, the intellectual world, or the total, combined world of all human experience.

That there is no exaggeration in this view becomes almost immediately evident when it is realized that understanding comes only through the grasping of ideas, for that is what "to understand" means, namely, "to get the idea." Now, mathematics deals with ideas, all of them thoroughly abstract and many of them of the subtlest type. Further, all of them are of the most pervasive type. They are met with at every step in life, at every turn, at every venture. Consider such simple mathematical ideas as number, ratio, proportion, length, area, volume, curve,

* Presented at the Middle Atlantic Section Meeting, New York, December 6, 1947.

surface, solid, sum, difference, product, quotient, equal, less than, and so on, and note how often one meets them in every-day life, and how difficult any sustained thinking would be without them. Consider next the more sophisticated, the subtler concepts of mathematics, such concepts as variable, function, dependence, rate of change, limit, infinity, transformation, correspondence, isomorphism, definition, postulate, consistence, induction, proof, truth, falsity, and so on, and note how utterly paralyzing their absence would be to scientific, philosophic, or any other kind of thinking on a higher level. This point need not be stressed further, for it should be evident that when these concepts are once grasped in the abstract (and therefore most general) form, then any particular instance of their appearance, any situation in which they might be involved in a concrete way, becomes immediately recognizable, that is, understandable again, since it was once understood in the general way. Thus relationships are perceived; bearings and connections seen; analogies, parallelisms and isomorphisms detected; in short, thus one begins to see the forms, principles, and relations common to many; thus the world acquires unity; thus life is understood.

This aspect of mathematics is the one stressed least in technical schools (as opposed to liberal arts colleges) on the ground that certain other aspects, to wit, the practical and the utilitarian, are more important to the technician, the engineer, or the scientist. But to the extent to which the technician, the engineer, and the scientist are also intelligent human beings, curious about the world and seeking to understand, to that extent at least the cultural aspect of mathematics is of importance to them and should therefore be brought within their reach. On the other hand, noting the growing emphasis being laid on technology in recent years, one could insist that prospective technicians, engineers, and scientists are the very persons to whom this aspect of mathematics should be stressed. For, in the more responsible, more commanding positions in life to which they are increasingly being called they shall have the greater need for broader understanding, both for their own sakes and that of society at large.

It seems indicated then that this aspect of mathematics should not be neglected in an engineering school since, besides, the extra amount of time it would require on the part of the instructor and of the student would be small indeed. The grasping of the mathematical concepts, relations, and operations is effected in the very act of learning mathematics; all that need be done, *in addition,* is for the concepts to be singled out by the instructor, to be held up for inspection as it were, to be commented on historically, philosophically, discussed as to bearing, growth, and clarification in time, and instances of their occurrence in life pointed out.

Logical Role

Closely connected with the aspect discussed above is the logical one for, by a proper recognition of the latter, light is shed not only on the nature of mathematics itself but also on that of the mathematical sciences.

Consider the syllogism

> Every man is mortal,
> John is a man,
> Therefore John is mortal.

The conclusion, "John is mortal," follows from the premises, by the laws of logic alone, from the form of the premises and in no way from the meanings

of the terms man, mortal, John. In fact, we can put x, y, z for these terms, thus

Every x is a y,
z is an x,
Therefore z is a y,

in which x, y, z have been assigned no meanings whatever, and see that none the less the conclusion "z is a y" follows just as inevitably. Now, mathematical propositions are of the form

"$p(x,y,\ldots)$ implies $q(x,y,\ldots)$"

in which q is deducible from p not through any particular meanings of the variables x, y,... but through the relation of formal implication alone, and for any values of the variables x, y,... for which p and q make sense, even though false. The mathematical proposition "$p(x,y,\ldots)$ implies $q(x,y,\ldots)$" is not concerned with the truth or falsity of either p or q; it merely asserts that if p is true then q is true or, conversely, that if q is not true then p is not either. Hence, if for certain values of x, y,..., p is true, then, for those values of x, y,..., q may be asserted. Thus, if in the mathematical proposition

"$(x : y = z : u)$ implies $(x = yz/u)$"

the values L_1, W_1, W_2, L_2, where the L's and W's are the arms and weights of a lever, are substituted for x, y, z, u, respectively, in the implier; and if the resulting proposition $(L_1 : W_1 = W_2 : L_2)$ is found to be true, then the implicate $(L_1 = W_1W_2/L_2)$ may be asserted, that is, the length of arm L_1 of a weight W_1 which will balance a weight W_2 at a distance L_2 can be determined without resort to experiment. It will be observed that any other proposition which follows from $(x = yz/u)$ will be true when the values L_1, W_1, W_2, L_2, are substituted for x, y, z, u. Again, if the undefined terms x, y, z,..., subject to the postulates P_1, P_2, P_3,..., lead to propositions T_1, T_2, T_3,..., and if the particular values x', y', z',..., representing physical entities of some kind, lead to the physical propositions P'_1, P'_2, P'_3,..., and *if these propositions are true,* then the physical theorems T'_1, T'_2, T'_3,... may be at once asserted, without recourse to experiment. The two systems

(1) x, y, z,...
P_1, P_2, P_3,...
T_1, T_2, T_3,...

(2) x', y', z',...
P'_1, P'_2, P'_3,...
T'_1, T'_2, T'_3,...

possess the same structure, the same form; there is complete parallelism between them. But the first is purely abstract; it is a mathematical system. It exhibits a mathematical theory. The second has physical content; it is a physical system. It exhibits a physical theory. This is the principal service that mathematics renders to science, and therefore to engineering too, since the latter is nothing but that part of science which is immediately devoted to human needs. In such sciences as Mechanics, Electricity, Magnetism, Fluid Mechanics, Conduction of Heat, and so on, the fundamental laws, or assumptions, of the science are expressible in mathematical symbolism as mathematical theorems. From these theorems certain others follow, by logical implication alone. These are the theorems of the physical science, after reinterpretation of the symbols back into physical meaning.

The convincingness of the physical theorems stems from the proofs of the corresponding mathematical theorems of which they are counterparts; and

these proofs, it should be noted, are derived entirely without appeal to the meaning, or content, of the symbols involved. On the other hand, if a physical theorem thus derived fails to meet expectations in the laboratory, that is, if it is proved false by experiment, then doubt is cast immediately on the adequacy of the physical laws, or assumptions used in its derivation. A revision of these laws then becomes necessary. This is, of course, the meaning of the Scientific Method.

It is to be observed that the more fundamental the physical laws assumed are, the closer the correspondence between the mathematical and the physical theories can be made. Few physical theories have their fundamental laws statable in terms of the initial axioms of mathematics (the few exceptions are the correspondences usually made between the real number system and the system of magnitudes, say, or the system of measurements, etc.). Hence, in actual practice the correlation is not as complete as that shown in the systems (1) above. Physical investigators do not establish a correspondence between the elements of their science and those of an abstract mathematical system and then examine the results to see whether the postulates of the abstract system, with concrete elements substituted for the abstract ones, do become true propositions, that is, the true laws of their science. Instead, they find it more convenient to begin somewhere in the middle; they make a shrewd guess as to the fundamental laws of their science, they express these in mathematical symbols and then, treating the results as abstract mathematical propositions, they deduce their formal implicates. Next, by interpreting these implicates as concrete scientific propositions they seek to find whether they are true or not, by an appeal to experiment if necessary. As long as the interpretations of the formally deduced propositions give true scientific laws, verifiable in the laboratory, the investigation may continue. But if one single interpretation turns out to be a false scientific proposition, then it is immediately evident that something is wrong in the assumptions made. A revision, new guesses, or modifications of the old, must be made.

Utilitarian Role

It is clear then that intelligent scientific work demands, besides a knowledge of mathematical theory, the ability to express physical laws, physical relationships between composite physical entities, or varied combinations of these, in abstract mathematical symbolism. And since, in solving engineering problems, the work is, essentially, one of scientific investigation, an engineer must have the ability of breaking up a problem into its constituent parts, in terms of physical principles, or derived laws; he must have the ability of expressing these parts in mathematical symbolism, the ability of setting up an equation, or equations, embodying the conditions of the problem, and the ability (a mathematical ability now, involving no scientific knowledge) of making formal deductions from the equations set up until a result is obtained which gives the solution of the problem. This he must, in general, be able to recognize by an interpretation of the mathematical deduction into scientific terms again. Hence it follows that among the aims of mathematics courses in an engineering college should be those of developing the following abilities:

(1) that of analyzing a problem into fundamental, constitutent parts;

(2) that of expressing these parts in mathematical symbolism;
(3) that of stating, in terms of such symbolism, the relationships that hold among these parts;
(4) that of technical manipulation of the resulting abstract forms;
(5) that of interpretating the result of such manipulations in physical terms.

Technical Role

It is obvious that a technical knowledge of mathematics, purely as mathematics, is necessary. The engineer must know his Trigonometry, his Algebra, his Analytic Geometry, his Calculus, and so on, if he is to set up his problems in terms of the concepts and operations of mathematics, and then handle the resulting mathematical expressions, in a mathematical way, until he arrives at the deduction he seeks. In fact, it is held by some that that is all that is necessary. For, they argue, in the very act of learning mathematical theories and techniques the student is bound to absorb some of the philosophic principles, some of the breadth of abstract ideas, some of the logic and formalism, some of the bearing on science, and some idea as to applicability to physical problems. There is some truth in such an argument, of course; all four aspects of mathematics are involved together in mathematics, and the student is bound to come in contact with the others in the mere act of mastering the technical part, but inasmuch as all four are essential (even though not to the same degree) each is worth separate mention, identification, and individual handling. There is overlapping, of course, and intermingling; in fact, there is actual unification of all four aspects. But each contributes its maximum benefit as it, itself, is clearly perceived. And it is true here, as in any other teaching, that the teacher has a helpful role to play in pointing these matters out, in planning the course, and organizing the material so as to enhance the benefit conferred by each.

Creative Work in Engineering

By J. F. CALVERT

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I. The Creation of New Devices

Original designs and inventions are the foundation stones in the advancement of engineering. Improvements in existing equipment, new devices, and new industries are built upon the inventions or creations of new types of physical things brought to being through men's imagination.

In the past in mechanical design and, to some extent, in electrical design, a rather high percentage of the inventions have come from men without college degrees who advanced through an informal apprenticeship in the shop, drafting room, or laboratory. To produce many of the new designs of the future, it is almost certain that a greater knowledge of scientific fundamentals will be required than heretofore. Yet new products and new manufacturing industries can come only through the imaginative effort of men with a flair for creative design. This situation presents a definite challenge to those engaged in engineering educational work.

II. Design in Relation to Curriculum

The mathematicians use the term "analysis" to refer to such fields of study as functions of a real variable, series, differential and integral calculus, differential equations, etc. The term "analysis" will be used throughout this paper, at least in the general mathematical sense, as a form or type of thinking. It will be contrasted with the word "synthesis" which will be taken to mean the putting together of different things or ideas and will include the notion of a resulting intelligible whole.

The techniques of analysis have been the backbone of much, if not most, engineering teaching, and rightfully so. They permit the most careful statements of "basic principles" which principles are, by definition, those which enter into a multitude of problems, and contribute to their solutions. Also, analysis, as it stems from mathematics, affords a means for attaining sufficient accuracy in a profession where accuracy is of profound importance.

But, analysis is not the answer to all problems in even the technical phases of engineering. For the creation of new designs we usually need the capacity for imagining new combinations of material things and an approximately accurate "sense of the rightness" of these. New designs are not often analyzed into being, but are synthesized by bold qualitative thinking.

We need to consider the nature of design and development and, at the risk of some inaccuracy, might state that there are two major divisions of each complete problem:

A. The initial stages of design usually deal with questions in a qualitative

way. The problem must be discovered and stated, possible methods of solution must be synthesized or invented, and finally an evaluation and classification of the potential methods is required. Often, even the last may be done largely at the qualitative level.

B. The later stages of design deal with matters in a quantitative way. The process selected for the solution of the problem is refined and developed in detail through the application of known techniques of analysis. The basic idea is given form and dimensions through the use of calculations, drawings, scale models, and the construction of pilot models.

In the past, formal engineering education has rarely included practice in the first, but often has included training in the second or more nearly final stage of design work. Instruction in the latter has been characterized by two general procedures. One has been to teach basic design techniques without completely designing any specific device. A great proponent of this procedure was the late B. G. Lamme. In his electrical design schools were taught such subjects as the calculation of magnetic, electrostatic and other steady state fields, e.m.f.s, m.m.f.s, iron and other losses, and ventilation and cooling in electrical apparatus. On occasions both static and rotating equipment might be introduced to illustrate a single subject, but in general no machine was completely designed in this school. Another procedure has been to teach some basic design techniques, but primarily to emphasize their use through the derivation and application of formulas which were developed for the design of specific machines.

Each of these procedures, concerned with the more nearly final stages of design, has its advantages and its shortcomings. The first has the virtue that all techniques have, in themselves, very wide applicability and also they may serve as the bases for the development of more specialized design formulas. The second method gives the student a sense of the size and shape of equipment and of some of the economic considerations, but in the process may require the development of a number of specialized formulas which are not exactly those used by any manufacturer and which in themselves are not of very broad educational value.

Basic techniques, and methods of applying them, must be learned by those entering the fields of design. However, the discovery and stating of the problem, the synthesis of possible solutions, and the evaluation of the latter also should be studied. The latter, taken as a whole, comprise the initial stage of design and are vital to the development of new devices.

Many people assume that an invention or a new design can only result from an unexplained flash of genius. It is certainly true that the one who produced the central idea cannot always say exactly what brought it about. There are, however, all sizes of mental steps. Many simple ideas experienced in everyday life, as well as others occurring in specialized technical problems, though much less startling than great inventions, are similar in character to these larger mental achievements. There are recognizable patterns of thought involved in the solution of such large and small problems, and they can be described with some degree of accuracy. Also, certain procedures, judiciously employed, should enhance the chance of success in creative engineering. The purpose of this study will be to explore some of the

types of thinking done and some of the factors related to such creative work. Suggestions of a preliminary nature will be made to show how such design ability might be developed. While one may see many interesting possibilities outside the field under discussion, this paper will be confined primarily to the initial phases of engineering development and design.

III. Design in Relation to the Individual

Choice between alternatives seems to be the almost incessant occupation of those engaged in science and engineering. It is as if the mind acted as a probability filter or sieve into which new observations came to be accepted or rejected in accordance with whether or not they could be incorporated as data which were consistent with past experience. This does not mean that all past experience is retained without change in the face of new evidence (heaven forbid!), but that the scientifically trained are presumed to take particular pains to keep their accepted experiences in orderly groups, with the elements of each group of "facts" consistently interrelated.

A. Steps in the Development of an Engineering Product

We need now to establish our assumption concerning (1) the purposes of design, (2) the usual steps which are taken in carrying through a project, and (3) the style of thinking required.

The work done on new designs (or new organizational developments in engineering) is not done to gain knowledge for its own sake, but to produce something which will be used.

In present day engineering, work on new equipment is usually done by

TABLE I

Details Which May Be Involved in a Complete Engineering Design Problem

1. The Human Part of the Problem.
   (a) The recognition or discovery of a human need or want, real or potential, which might be satisfied through the application of the principles of the physical sciences.
   (b) A statement of the physical result, or results, which it is believed will satisfy the need. This, or these, may take one of several forms as shown below:
      (1) A single physical result.
      (2) A single group of results, no one of which excludes the existence of another (even though practical methods of achievement are unknown).
      (3) Several possible results, or groups of results, with a sort of grading procedure established. Such a grading system might involve a minimum performance for each possible result. Then a sort of "figure of merit" would be needed so that those potential solutions which might meet all minimal requirements could be compared and ranked according to their order of relative value. This kind of grading procedure (if it could be agreed upon) might permit a comparison of the possible physical systems for achieving results not only after the fairly complete development of each, but at various stages along the way. Conceivably it could be used to stop investigation upon some system under study so that greater effort could be placed upon the more promising systems.

   In any of the above it is assumed that cost in dollars, date of completion, etc., are likely to be involved in the requirements upon the results to be obtained.
2. The Physical or Engineering Part of the Problem.
   (a) Probably a restatement of the problem in more exact terms. This may involve mathematical relations.

TABLE I—*Continued*

(b) The discovery or invention of possible physical systems which it is believed may prove to be satisfactory.
(c) A clarification of each system which seems to warrant development.
  (1) Statement of the assumptions (which usually means slightly "simplifying" the problem or, in reality, defining another problem that is believed to be sufficiently close to the actual one to give results which will also be close to the actual. Often the problem first is "simplified" beyond this, with the idea of starting through again and again, with additional factors included each time as more experience is gained).
  (2) Development of a procedure for the analysis and then its employment. This may involve both tests and calculations, and require in some cases the discovery through tests of new physical facts either general or else limited by the specific conditions of the problem at hand.
  (3) Tabulation and interpretation of results.
  (4) A pondering of these results and their interpretation in terms of the desired physical results, and of any new evidence or limitations which have come into view.

3. The Judgment of the Engineering Solutions in Terms of the Human Needs.
   Making a choice of one or more of the engineering solutions under Item 2 which may best meet all the requirements set down under 1(a) and 1(b) above.
4. The Detailed Design and Construction.
   This statement seems self-explanatory. Detailed designs are prepared and construction undertaken either on a pilot model basis or for full scale development, or both but in sequence. This item will not be discussed further since the paper is concerned with the initial phases of design.

research and design teams in which there are various specialists to furnish aid and support to one another, yet the "unit" producing a single idea is one human mind. Thus, the individual to be effective must be able in his own right, but, at the same time, have a rather good idea of where his efforts fit into the whole project. We shall look at the work of invention and design from the point of view of a single individual, but assume that he is working as one of a group.

The factors related to the production of a new and successful design are the recognition of a need, invention and design, production, and sales at a profit. The steps involved are outlined in Table I with emphasis placed on the initial stages of the work.

Many times an engineer is working on only one phase of a large project which actually involves something of each of the main parts listed above, but it is still well for him to know where his work fits into the whole.

B. What is Needed for the Solution of Engineering Problems

Solutions to engineering problems come from human minds, not from machines, laboratory equipment, or calculating techniques. The latter are to provide data and support for the designers' imagination and judgment. Table II is concerned with the mental "equipment" required.

Observation and discrimination are vital attributes in every laboratory science. They are abilities which are well understood, and excellent training is given for their development.

Memory is an ability to use with some care in design work. Long-time memory should be used to retain basic principles, to say where to find details, and to advise who is known to be an expert in one's own and also in related fields of study. Facts, figures, formulas, integral tables, etc., are all in

the books and need not be carried in the head. Short-time memory is another matter.* When engrossed in a problem, one must retain a surprisingly large amount of information for ready use at any one time in order to permit the proper play of imagination and judgment. Here analogies and other tricks of simplification can be of great value.

TABLE II

MENTAL ABILITIES INVOLVED IN PROBLEM SOLUTION

1. Observation and discrimination.
2. Memory.
3. Logical thinking—with emphasis upon mathematical analysis, other forms of mathematical work, or analogous types of effort.
4. Imagination—with emphasis upon the combinations of material things and of symbols to represent them.
5. Judgment—with emphasis upon—
   (a) Interpreting observations and discriminations.
   (b) Guiding the imagination (conscious or intuitive).
   (c) Making final decisions when all the available facts are assembled.

Logical thinking is so thoroughly and extensively treated in every course in the physical sciences, mathematics and engineering that it seems almost unnecessary to remark upon it. If there are matters worthy of further mention they are:

(1) that engineers sometimes do not write down their assumptions in clear, one, two, three style;
(2) that for clarity they could often afford to break a report up more sharply into the four parts shown in Table I under Part 2(c), and
(3) that they could always get both the assumptions and the conclusions together in one place in short and concise form which others can easily understand.

IV. THE NATURE OF IMAGINATION AND JUDGMENT

Imagination and judgment seem inseparable in relation to invention and design and will be discussed here jointly and intermittently throughout what is to follow.

Creative design and invention require the knowledge of science but the spirit of art. Some inventors have felt that to achieve in design, one must become attuned to nature in order to project forward in time as does the painter who sees the form and color of the finished work in oil, or the musician who hears and feels the new passages of a yet unwritten theme, or the sculptor who can envision a finished statue in a block of marble, or the inventor who may see the fit of airfoils to the air stream like wings in the wind. Sikorski speaks of intuition in invention as the "forerunner of knowledge" which tells of the correctness of things and which later may be proven by observation and analysis.* Yet all of this stems from imagination, a series of forms, colors, sounds, or images which occur in the mind, and intuition is the sense of rightness which says, "Stop, this is it, the meaningful

* Probably any facts which are used for a reasonable length of time are recoverable if a sufficient number of hints are offered at a time when extraneous subject material is excluded from the mind. However, for most practical purposes, that which is used intensively, for a few hours or days or weeks and not likely to be needed again, is relegated here to the short time classification. After use, it should go into "dead-storage" in order not to clutter up the more needed areas.

* Ref. 4, pp. 3 and 4.

whole." And you stop to see if it really is true.

If this is what we seek, what may be done about so sprightly a thing?

First, it is well to remove, if it exists, a common feeling that "mute, unconscious intuition is emotional, not intellectual and scientific, and therefore, not to be desired." ** Danger may exist of rationalization, true, but this may be tested later by the sterner processes of logic or of the laboratory.

Also, it might be noted that scientific logic is often only quantitatively exact about slightly unreal situations, while imagination (and intuition) may be qualitatively correct regarding more involved problems.

Next let us consider the inferences made in everyday life. They seem to be simple acts of imagination and of intuition. It would be difficult to say how you recognize the sound of one person's feet; or, how else you can distinguish one person from many others, be it only by hearing a single spoken word or by seeing the creases in his shoes. For motoring at night down strange roads which bear no formal signs, one learns to predict with speed and accuracy the turns, hills and valleys. In the main, the inferences made in such matters turn out to be correct conclusions. They seem to be arrived at intuitively from insufficient data, but can it be insufficient when the results are so often true? Sometimes at a later date we believe that we can deduce from what and how the intuitive conclusions were drawn. It is highly improbable that intuition in these cases is a persistent arriving-at-right-answers from wrong premises and by illogical routes. Is not intuition similar to reason but not active at the conscious level? *** In one case we can write it all down, in the other we cannot or do not do so, but probably the steps are essentially the same. Thus we see the laborious proof of correctness arrived at by conscious logic in contrast with the possible flash of probable correctness (intuitive judgment). There seems to be a plodding stolidness about the steps of logic as compared with the rushing about through space and time which the imagination will do in preparation for intuitive action. In the one, the steps are sure and slow; in the other, more tentative but more rapid. The difference may have an influence on inventiveness and will be returned to later, because it also seems to bear on one's training and practice.

Apparently we can develop the ability to think in many kinds of imagery and try various combinatioins for rightness, and also it seems apparent that this process can go on at times without conscious effort, yet come to correct conclusions. Therefore, should we not consider how we may consciously develop the art of imagery and with what conditions we may surround ourselves to favor the intuitive process in order to arrive more often at the probably correct conclusions? We shall endeavor to do this, but first one brief word regarding the practical.

There is a vast difference between the "crack-pot inventor" and the designer of successful new devices. Each must have developed that knack of arranging in the imagination the new and novel, but the difference is measured not by the degree of newness found in the ideas, but by the judgment with

** Ref. 4, p. 20.

*** Perhaps it would be more satisfactory to define intuition as a combination of reason and judgment based upon unrecognized or subliminal cues.

which they are weighed. Questions must be asked and answered. Why is this job worth doing? Is the magnitude of the improvement likely to be such that it will be unquestionably accepted, or is it apt to be only of a marginal sort at best? What will it require in men's time, in money, and in materials? It there something else which should take precedence? Yet these necessary appraisals should not be allowed to dampen one's ardor for achievement.

V. Imagination and Judgment in Initial Design

A. Aids for Imagination and Judgment

A person may be seeking a need for a product or a product for a need. Thus at one time new uses were actively sought for both artificial rubber and for spun glass while, during the early days of World War II, German developments on the magnetic mine made many degaussing designs mandatory.

The discovery of the human need to be followed by an engineering solution is the sequence which will be assumed below. In such work there are needed (1) a storehouse of knowledge arranged to suit the designer's way of work, (2) an initial statement of the problem at least in general terms (and to be made specific as rapidly as developments permit), (3) a "soaking-in-process," wherein the designer seeks to encompass within his ken an array of facts and possibilities related to his purpose and to try various combinations of these, and wherein the designer makes a gradually increasing use of the technical literature for support, (4) a final careful restatement of the problem and of the proposed solution with the attendant evaluations.

B. The Storehouse—Human Needs

The storehouse must contain in a reasonably orderly fashion "facts" and "hunches." Of course these "hunches" or conjectures must be carefully tagged, but they should be given an appropriate tentative status. There will be a trend toward orderliness and hence availability of ideas on human needs, if they are put away in accordance with some system. Such ideas might be classified according to existing industrial products or, perhaps, in terms of some list such as that suggested by Table III.

C. The Storehouse—Working Tools

We have talked of human needs. Next we should see what the designer's storehouse should hold in that large part allotted to physical things.

Ideas are needed on the properties and the potential uses of materials. Thus, we like to know if they corrode easily, change resistance with temperature, obey Hooke's law, if they are electrical insulators or conductors, if they shrink with age, and if they are brittle or pliable. Besides such general ideas, where should we look and to whom should we go for the detailed and very unusual facts? Also, we might well carry around a few ideas on what groups of properties we would like but have never seen in any single material. It does not pay today to sell short the chemists or the metallurgists. If they don't have it yet, it may be on the way or even developed now by modifying some existing synthetics or alloys.

Electromechanical designs so often involve in their makeup gears, cams, linkages, ratchets, Geneva movements, etc. The designer should embrace certain ideas regarding:

1. Possible types of motion.
2. Ways of producing one motion from another.

TABLE III

ONE POSSIBLE CLASSIFICATION OF HUMAN NEEDS

1. Preservation of one's own life and to a lesser extent health are ever present needs. Weapons were developed early. Today a widening and deepening of the air lanes as well as automatic blind landing systems seem necessary to make safe the coming volume of air traffic.
2. Savings in economic values as defined by money, man hours and materials account for most, though not all, engineering developments, but perhaps too many engineers have held closely to the strictly engineering uses for designs. There has been much opportunity and should be more in satisfying the needs of the home, of agriculture, of merchandising and of medicine.
3. Individual freedom of action. Greater facilities for travel and communication are prominent examples. Are there others?
4. Comforts in terms of any of the senses have been the wants upon which immense industries were built, yet each year we endure much heat, cold, drought, dampness, blinding light, disturbing darkness, unpleasant odors, smoke, dirt and wearing noises. Means for the further reduction of some of these annoyances might be justified to the user, not only on the basis of comfort but also of direct economic gains.
5. Amusements and escapes from the daily requirements of life only need mentioning to bring to mind hosts of growing industries.
6. Release from drudgery. Engineers have applied much thought to home, farm and factory equipment, yet in the factory and in the office efficiency has so often been measured primarily by the stop-watch, the time card, or else the number of square feet of paper turned out by a typist or a draftsman. To some extent these may serve as measures and thereby as incentives. Yet there must be millions upon millions of human beings who would rise to greater levels of productivity if their work were made more interesting and more stimulating.

TABLE III—*Continued*

7. Worry, anxiety, and fear appear from time to time as unwelcome visitors in every home and in every human heart. Job security, adequate medical care, and educational advantages for their children are of paramount importance to most parents of only moderate means. Can the engineer do something toward "leveling out" employment, help to make medical care less expensive, or to improve general educational procedures?

3. Methods of representing in various fashions certain operations such as addition, subtraction, multiplication, and integration.

Some things worth knowing about electrical circuits are:

1. How to get from one voltage to another in both alternating and direct current circuits.
2. How to get one type of variation in electrical quantities to produce another.
3. How to represent the mathematical operations mentioned above, including differentiation.
4. The performance characteristics of motors and other transducers.

Too few electrical and mechanical designers are well versed in geometric optics and in photography. These are of particular value in measurement and test. A designer needs to know that choice can be made between mechanical, electrical, and optical devices, particularly in dynamic problems, on the basis of accuracy as well as weight, size, convenience, and cost. The elimination of one method in favor of another usually can be done early if the requirements and preferences have been clearly written down.

Mr. B. G. Lamme, is reported to have advised "watch the man who thinks in analogies." As one mathe-

matical expression may represent a variety of physical situations, much work has been done to classify the analogous parameters and variables in electrical, mechanical and acoustical vibrating systems.* If one thinks rapidly and fluently in one system of symbols but not in another, he may establish the analogy in his own language and proceed with the expectation that he can translate back again later on. This is all right for qualitative work, because rigorous procedures probably can be introduced later for calculations on the original system if there are some "extenuating circumstances."

D. The Statement of the Problem

Thus far we have been considering the arrangement in the mental storehouse of the tools for initial design. The "soaking-in" process is where we try to use them; but first the desired physical results must be defined, at least in general terms, before we can imagine what may be done about achieving them.

The statement may seem strange, but oftentimes a person starts without knowing just what he wants to do. Sometimes one just "does not like the way the thing is being done," and at other times feels "there must be something missing here." These responses are perfectly natural. However, to avoid meaningless day-dreaming it is necessary to get the desired result stated as quickly as possible, *if only in general terms*. What are we trying to improve and why, or what is missing? The first definition of result does not need to be so well refined that it could be given out immediately to someone else as a problem, but if not then, as one starts to think of the ways and means and to marshal all relevant knowledge, he should continue to define and to redefine the results desired until they stand as sharply as beacons in the night.

If a man can state concisely what belongs under each of the three headings shown below, he will have gone a very long way toward defining the problem:**

1. To produce (if it is a design problem:).....or to determine (if it is an analysis or test job:).....
2. To overcome the specific obstacles of:.....
3. In such a way as to attain the specific aims of:.....

E. The Soaking in Process

In his imagination a small child makes himself the central figure in a story and enjoys the excitement of the terrific situations which he creates. A designer should dream for a purpose —one purpose—to obtain the result he has defined. Nevertheless, he needs at first to have a free running imagination which is working smoothly at many periods of the day in order to fit together various images which may achieve his goal. Quite frequently no good solution is found before he has touched, even though lightly at times, upon almost everything which conceivably might be employed. Since a new idea usually means a new combination of known information, the job is to increase the likelihood of the right combination appearing and of being recognized as the desired "meaningful whole." Since the designer does not

* Numerous papers and texts are available, and the individual may make additional classifications of his own.

** Arrangement suggested by Dr. R. H. Seashore, Chairman, Department of Psychology, Northwestern University.

know what it is to be, he should try to shade the probability in his favor.

Systematizing may help. Thus the selection of the most likely fields or areas in which to work and the elimination of others may be first steps, yet some consideration of the bizarre may also yield results. If something has always been done one way, one might consider briefly at times what would happen if it were done in the reverse or in some other order.

A man cannot build up a very intricate idea or keep from repeating himself without the use of visual aids. Some sort of shorthand techniques are needed which do not hold him back or distract him from his main ideas. Block diagram procedures such as those used in radio work may be used in many fields of engineering. When needed, vectors should be freely employed. At times one may care to invent symbols when he knows of no simple standard types, such as for gearing, bearings, friction elements, masses, shafts, etc.

Ability at free hand perspective drawing is an art well worth developing. Paper may be secured with guide lines for perspective and also for isometric drawing. Either of these may be useful to the less well trained at sketching.

When the designer feels that ideas may be sufficiently well formed, he should try writing them down with brief diagrams, drawings, symbols, etc., as needed, but with no delay set in through the normal requirements of grammar and of completeness in mathematical work. He may get just enough down to sketch out the whole or a large part of the job. Thus, any good sequences of ideas are caught at a time when they are fresh in his mind, and errors and omissions in the overall plan are likely to be quickly exposed.

It is well to remember that nothing is much faster than conversation for the exchange and correction of ideas. It is possible to cover ground much faster in a qualitative way by this procedure than either by reading or writing or both. People who will listen and discuss one's problem can be of invaluable assistance. The mere act of explaining out loud assisted, perhaps, by brief sketches on a blackboard or on paper will force the marshalling of the designer's thoughts and will tend to show up their weaknesses. The remarks of others often initiate or "trigger" thought on unexpected possibilities.

If a contemplated device contains moving mechanical parts, a rough wooden model (possibly metal, if gearing is involved) can be of immense help for getting satisfactory proportions and for indicating needed checks on clearances, etc. Usually the model does not need to be a polished job. For instance, in a wooden model a nail may serve for a bearing or else afford limited flexibility between parts.

Thus far we have dealt with knowledge and techniques. There are certain other factors which are related more to personal habits and behavior.

If the designer expects to have new ideas it is a fairly good rule to try to lay the groundwork before mid-afternoon. Of course, there are some most outstanding exceptions to this idea, but it seems to be accepted as generally sound. Sometimes it is necessary to live in the job day in and day out, and if this is not possible, then to so live at as many spare periods of time as can be found. This means enthusiasm for hard work and lots of it.

Eventually such continuous striving, if carried on without much success, will lead to great frustration and discouragement. Some have thought this to be a part of the productive process, since it may drive the mind to results. However, I think that usually extreme frustration is only the result of the common, but not necessarily good habit of hanging on beyond the reasonable limits of endurance. The habit may be often incident to, but not necessary for getting results. Certainly if the feeling of frustration and dissatisfaction gets bad enough, it will force one to seek release in other activities. The rest, change and return to the problem as from a distance are likely to turn the trick of finding the answer consciously or unconsciously. (We seem only to read about the cases where the idea comes in without being sought, but this is, of course, the more spectacular sort of entrance for an idea to make, and hence we should expect to hear more of it.) It is most likely that a good deal of wear and tear can be saved by deliberately changing the scene before one gets into such a state of fatigue, and perspective may be gained upon one's return to the problem.

Nothing has been said thus far about the use of books, technical papers, reports or other aids which go under the name of bibliographical material. Certainly the problem should be pretty clearly stated before any reading is undertaken. How soon thereafter one should start reading is very hard to say. If an early start is made, it may save time and again it may keep one from hitting upon anything new. If the first rush of ideas are put on paper before reference is made to the literature, one may increase the "hit expectancy" of a new idea but he may also shoot up "dead ducks" that others have laid to rest long ago. Nevertheless, there are a good many cases where the careful library search should be delayed for several days while the salient possibilities which are likely to occur have come to mind.

F. The Final Statement of the Problem and of the Proposed Solution

Finally, when the plan is sketched out which appears to be sound, the designer must change from the imaginative thinking in qualitative terms to the analytical work in quantitative terms. The object or desired result must be very carefully restated and the usual sort of rigorous calculations, tests, and reports on the design must be worked out. Limitations, advantages, and disadvantages of the plans must be sought and weighed as dispassionately as if they were being proposed by someone else. This is the frame of mind to be sought for in the last stage of a design project. The difference between this phase of the work and that of the imaginative phase cannot be overemphasized, yet ability and control are needed by the successful designer for each of these parts of the work.

With the statement of the proposed solution should go an evaluation of the proposed product. Two kinds of evaluation are desirable, one by experts (engineers and scientists) who may perceive the technical possibilities of failure and the other by representative users as they are more likely to see the probable operating inconveniences. Many large companies make systematic inquiries among critics of both types.

VI. Formal and Informal Training

Thus far, there have been outlined some of the abilities and skills which

are required in problem solving during the initial stages of design. I believe that latent abilities for such work exist among a much greater number of persons than is commonly supposed. The discovery of design ability is not undertaken today on a very scientific basis. The development of skills takes place largely through an informal apprenticeship in the industries. What further can be done about the discovery and development of ability for creative design?

Sufficient advances have been made in educational methods to permit the correlation and development of the needed teaching techniques in that area which we have called the initial stages of design. It appears that a case method or problem solving approach is likely to be the most fruitful. Let us look briefly at what the colleges and the industries might do in a somewhat coordinated program.

Constructive work hardly may be undertaken before the senior or graduate year, but spade work can be done earlier than this. After the basic principles of physics, mathematics and engineering are learned, considerable strength can be developed in the student through project type of laboratory experiments, and this is done in many colleges. The student may be told that certain end results are desired, and he can be advised of the equipment available. He can be asked to plan

TABLE IV

POSSIBLE AREAS FOR PROBLEMS

A. Preservation of Life and Health.
   1. Loss of time from common colds.
   2. Measurements for predicting the performance of the heart.
   3. Danger of falling on icy streets.
   4. Snow removal.
   5. Protection of pedestrians at street corners.

TABLE IV—*Continued*

   6. Summary of and the potential solutions for some of the problems in air traffic.
   7. Staying awake when driving a car.
   8. Reduction of hazards caused by "other" drivers.

B. Saving of Economic Values.
   1. Reduction of maintenance costs on your own car.
   2. Reduction of time spent in cooking.
   3. Same on dish washing.
   4. Same on house cleaning and daily upkeep.
   5. Wasted energies in office work as they result from
      (a) No quiet hour for telephones,
      (b) Calling and finding a man out,
      (c) Lack of consideration given to temperature and humidity,
      (d) Noises of all sorts, and
      (e) Clumsy filing systems for items of short and long time value.
   6. Handling of freight billings and tickets on railroads and other carriers.
   7. Lack of quick deliveries and pick ups needed only occasionally by small businesses and professional people.

C. Influences on Individual Freedom of Action.
   1. Verbal and visual communications.
   2. Slowness of letter writing.
   3. Time spent on transportation including securing reservations.
   4. Automobile inconveniences such as
      (a) Tire changing,
      (b) Cold cars on short runs,
      (c) Steaming up of windows,
      (d) Starting troubles, and
      (e) Parking troubles.

D. Comforts.
   1. Keeping cool when out-of-doors in hot climates.
   2. Blinding lights when driving.
   3. Subway and other traffic noise and vibration especially on steel wheel cars (noting, however, that the sound of the wheel when struck with a hammer is used to check its mechanical condition).
   4. Elimination of odors at home and at work.
   5. Radio interference in crowded areas.
   6. Smoke and dirt in areas where soft coal is burned.

the test, to carry it out, and to analyze the results. Courses like those concerned with open and closed cycle control systems, involving electrical, mechanical, hydraulic and pneumatic parts, may be used to correlate and to apply much previous learning.

Actual practice in the preliminary stages of design may be gained by some students in senior seminars. A student may have submitted to him a list of potential problem areas somewhat like those shown in Table IV, and he may be invited to devise ones of his own. He should then state a specific problem and carry through to the point of starting the actual final design. Thus, he needs to state the problem, devise methods of solution, determine which one he regards as the most promising, and evaluate the probable value of the design if it were completed.

There are large as well as small scale research projects concerned with design which are now in progress in many of the colleges of the country. Much work done by these groups goes through a formative or initial stage of design. Part time employment on research contracts can be of particular benefit if the student not only serves as a helper, but is told during the apprenticeship of the steps taken by the engineers in devising and choosing the courses of action for the various jobs.

The same is equally true of employment in industry. Younger men with desires and presumed potential abilities for design may be placed where they can see work both in the formative and in the later stages of development. Yet again it will be necessary to explain to them what was done and why. Possibly the student might report in writing on these matters so that his thinking becomes clarified and so that it is checked for soundness by those to whom he reports.

VII. Final Remarks

It may be well to repeat that engineering advances and new industries spring only from creative thinking and much of it in the fields of design. Native abilities in the field are national heritages but the development of these is the joint responsibility of the schools and of the industries. Motivation is of primary importance. Those of ability who are motivated and trained will find design to be for them the most fascinating work in the world. It is particularly important for us today to invent new ways to find and to develop abilities in design.

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Methods of Chemical Engineering Laboratory Instruction*

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Before one can begin to discuss the methods of chemical engineering laboratory instruction, an analysis should be made of the objectives sought. Without attempting to itemize these in order of importance, since in fact they are of comparable value, I submit the following:

1. The development of a chemical engineering point of view as contrasted to the chemists' or test tube outlook.
2. The development of the ability to present intelligible and useful reports both written and oral.
3. The development of the ability to think independently, or what may be termed the development of the research attitude.
4. The organization of previously learned chemical engineering information with the clarification of doubtful points which a student often carries with him from lecture instruction.

To these items should be added another which assumes considerably lesser status, namely some actual experience in handling pilot-plant type equipment. This item is listed as being of less importance since it is impossible in any laboratory to get thoroughly acquainted with all important types of industrial equipment, and this familiarity can be obtained in a much more useful fashion in the actual chemical engineering plant. Nevertheless, it cannot be denied that once one has operated a filter press, another type, even though different in construction, is much more easily understood.

It should be realized at the outset that a single course may not be sufficient to permit the obtaining of the objectives listed above. It is the purpose of my discussion this afternoon to outline for you how we at Princeton believe they can be accomplished. Nothing very novel or new is suggested and yet we have modified our undergraduate program of study in the last year in order to permit what we believe is a more satisfactory approach to the solution of these problems. This modification is now before the University faculty for final approval.

All students in Chemical Engineering should have a basic course in unit operations laboratory. Such a course may be fitted within the limitation of one semester of fifteen weeks. It can contain approximately nine experiments covering the major unit operations: 1. Fluid flow; 2. Heat transmission; 3. Multiple effect evaporation;

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4. Humidification and air conditioning; 5. Drying; 6. Distillation; 7. Filtration; 8. Gas absorption or Extraction; 9. Instrumentation.

These experiments must be fundamental in character; they should be designed so that the basic equations applicable to the individual process may be analyzed. For example, a fluid flow experiment should give ample opportunity for applying Bernoulli's theorem and the correlation of friction factor with Reynolds number. Such an experiment could also make use of orifice or venturi meter calibration and could involve the measurement of pressure drop due to pipe fittings. Similarly the heat transfer experiment would most profitably be on countercurrent heat transfer with a check on such relations as the Dittus-Boelter equation. Multiple effect evaporation is suggested as being more informative than a single effect experiment. Distillation is best carried out with a bubble-cap column rather than with a packed column or by use of simple or steam distillation. Similarly, each of the other experiments should be so chosen as to emphasize major points. It is clear that in a short course all possible variations and even all important items cannot be covered, but the course will serve to introduce the student to the important fundamentals of the chemical engineering laboratory.

All of the experiments need not be of the same length. However, a laboratory day of at least six consecutive hours is preferable. This is normally accomplished at Princeton by beginning the laboratory period about 10:30 in the morning, in other words after two or three lecture periods have elapsed, and carrying it through the noon hour and the afternoon to give sufficient time for the completion of any experiment even where difficulties are encountered. Experiments on fluid flow, heat transfer, distillation, mass transfer and the like require this continuous length of time for the best interest of both student and instruction. Other experiments, however, such as humidification and air conditioning can be carried out in much less time, usually three hours. For example, the Princeton experiment on humidification makes an operational study on the unit which supplies conditioned air to the Frick Chemical Laboratory. This is a commercial unit and while it does not permit alteration of operational variables, it does give the student a chance to make a test on a large-scale installation and determine whether or not it is operating correctly and to suggest improvements. A recent class, as a matter of fact, was able by its recommendation to improve the efficiency of this particular unit several percent.

It is believed that an experiment loses its value if the entire time is devoted to manipulation with relatively little time allowed for thinking it through. Therefore, each student is granted an amount of supervised calculation time equal to the time required to perform the original experiment. It is not the purpose of this supervised period to "feed" the student the necessary information for calculation but rather to provide him with skilled guidance when he needs it as he organizes and correlates the data. Thus by having six experiments requiring one full day each for their performance and three experiments requiring only half a day each it is possible to provide a student with an equivalent amount of calculation time and still complete the course in fifteen weeks. It will be expected that the actual writing of the engineering re-

port will take place outside of supervised hours.

It is felt that this report should be rather formal in character for at least the major experiments and should include a title page; table of contents; abstract; introduction and objective; conclusions; theory; apparatus, raw materials, etc.; procedure; results; discussion of these results and summary; together with a survey of the literature cited, and an appendix including calibration and record charts, detailed data, and of course sample calculations. The drawings and graphs submitted with the reports should be made in engineering style, and in all respects only top quality product should be acceptable. In order not to burden the student excessively, certain of the experiments can be reported in abbreviated form, each student in general being required to submit two formal reports and one abbreviated report in the elementary course. It is only by insisting on the highest of standards that the student will be impressed with the necessity for quality work. It is our experience that students want to please, that they want to learn how to do things properly, that they would rather do things right than wrong, but that they must be taught and their results must be criticized so that they will recognize wherein errors have been made. Such criticism, however, must be constructive and should be accompanied by individual instruction on the correction of errors so that the student will not make the same type of mistake twice.

It is fairly evident that in a beginning course of this sort quite a bit of guidance must be given the individual student. This does not mean that he has to be told precisely which valve to turn and what reading to take but at least a summary outline of what he is expected to do should be furnished him and instructors should be available to analyze his errors when they occur. For most effective teaching highly individualized instruction must be available. For this reason we have a ratio of about one instructor to each five or six students. Usually the laboratory is in charge of a senior staff member who is assisted by a member of instructional rank.

Now let use see what has been achieved in a course of this type. The student has been taught to make engineering measurements; he no longer thinks in term of calories per gram but rather in terms of B.t.u. per pound. Furthermore he no longer expects the accuracy of a quantitative analytical laboratory in all instances but realizes that sometimes an error of plus or minus 10 per cent represents good correlation; on the other hand he realizes that in some experiments such as those involving mass transfer, distillation etc., it is necessary to take highly accurate data if one is to get even approximately satisfactory results. Furthermore since he works on these experiments with two other men he learns the necessity for group cooperation. We employ the foremanship principle in which a single report is required of each group, the foreman being responsible for the successful operation of the experiment and the compilation of data. Each individual student must, of course, do his share on these experiments both in the laboratory and computation period and evidence of that is required, but the foreman is given double credit for those experiments for which he has responsibility in order to encourage him to do the best possible work.

In the computation section students are taught how to analyze and correlate engineering data and are given advice

on the preparation of an engineering report. The report itself is weighed heavily in determining a student's grade for only by emphasizing such reports can the criticism offered by industry that college students have not learned to express themselves properly be overcome.

However, the training of the chemical engineer in the laboratory has only begun. We have yet to give him any great amount of responsibility for thinking an experiment completely through by himself. Therefore, it is clear that additional laboratory courses must be provided. These need not be of the unit operations type but could be either the projects or process types of laboratory. Princeton feels that the curriculum should be tailored to the student's requirements rather than forcing the student into the mold of a course. Therefore, we provide three additional courses of which only one is required although an additional one may be elected. For those students who have shown their interests in the type of work exemplified by the production engineer, a one-year course in process analysis is recommended. This course is administered to groups of two men, each group being given a different process to analyze. In the laboratory the operational variables are studied and from these variables information which will permit the economic design of a plant is obtained. A requirement of this course is the design of a plant and a complete report covering the experimental data together with any literature data and economic information. This course quite obviously gives the student much more independent action. He is required to make use of the library, he is required to organize the experiment, determine what variables must be investigated, and carry the experiment to the point where all information necessary for his problem has been obtained. Formerly, a one-semester course of this sort was required of all seniors but it was noted that one term of two afternoons a week was inadequate to permit carrying it to its desirable state of completion. As a result it has been lengthened to a year course and made an alternate with the one now to be described.

While all students would benefit by the course that has just been mentioned some students have by this time clearly indicated their ability to do even a greater share of independent thinking and wish to get into the research and development fields. For them a senior project, or as some would term it a senior thesis, is desirable. In this type of work the student is given almost complete freedom of action, being guided only by weekly conferences with his director. Since each student requires individual instruction, this is a heavy drain on teaching personnel and this course is restricted to students who are likely to benefit by it as well as those who have indicated some promise of productivity in independent work. As before, a complete engineering report is required at the end of the investigation. Like the process laboratory this course formerly was given in one semester and required of all students but again it is felt that an entire year is more productive of real results and of more value to the department and the student.

One feature of both of these courses is the weekly colloquium or seminar in which the student discusses his work with the rest of the class and presents his plans and conclusions. Each student is expected to speak twice, once toward the beginning of the term when he outlines his proposed work and once

toward the end of the semester when he discusses his results. The spoken report is as important in industry as the written one and all students should be given an opportunity to participate in this type of exposition. Furthermore, very frequently valuable suggestions will come from other members of the class and a student who can persist in his defense of a thesis in the face of equally sincere opposition has the making of a good technical man.

For the same type of student we have just been discussing, namely the one who plans to enter the research and development type of work, an advanced unit operations laboratory is planned for the senior year. This laboratory, like thesis work, is a restricted one and may be elected only with the consent of the department. Here work of an advanced character in unit operations will be pursued. The squad system is employed and probably no more than five experiments will be attempted in one term. The laboratory like the more basic one is a full day in length, and at least two weeks are required for the obtaining of sufficient data to prepare a report on the assignment. One week is provided for computation and conference with the instructor. Assignments in this course will be made by letter from the department to the student outlining in broad terms the object of the proposed investigation but it will be up to the individual squad to set for itself the actual experiment and carry it through satisfactorily. Examples of experiments in this field are unsteady state heat transmission, heat transfer by radiation, fluid flow in which heat is involved, experiments in multi-component distillation, mass transfer experiments, and the like. In this course independence of thought and ability to organize are essential, and the report submitted will be critically examined for its engineering qualifications. It is clear that only senior staff members should attempt instruction in this type of work; in other words it should not be left to those of assistant instructor grade.

Let me recapitulate the laboratory work which an undergraduate at Princeton will be expected to study under our proposed curriculum. All students will have required of them a one-semester fundamental course in unit operations laboratory. The class will then be divided into two groups not necessarily equal in size, one of which will take process analysis laboratory and the other individual project or thesis work, thus making a minimum of three terms of chemical engineering laboratory for every student. In addition, a course in advanced unit operations laboratory will be offered for election to those men who have shown they can benefit by it. In this way we believe that all students will be given an opportunity to become familiar with the chemical engineering approach to problems, will be given opportunities for independent thinking and execution, and can demonstrate their ability as organizers and independent workers. Furthermore, ample opportunity in the field of report organization is not only offered but a high degree of excellence is required in the written and spoken report. As a natural consequence of these major objectives, the student will become familiar with actual types of equipment and their operation, limitations and points of usefulness and will have a chance to verify for himself the truth of the fundamental equations on which design is based.

Deans are likely to object to courses which require as high a ratio of in-

structors to students as is necessary to carry out this program properly, but if they can be convinced that it is only through laboratory procedure that the qualities of a good engineer can be developed they will usually accede to the teaching requirements that have been outlined. As a matter of fact it is possible with the judicious use of lower salaried staff, such as instructors and assistant instructors, to reduce the cost load of such a laboratory appreciably.

Once again I wish to emphasize that what is proposed is a basic chemical engineering laboratory program and it is presented here for the benefit of joint discussion in the belief that it or similar programs must be adopted if all the features desirable and attainable by laboratory instruction are to be achieved.

Sections

The 1948 meeting of the **Illinois-Indiana Section** was held at Illinois Institute of Technology Friday and Saturday, May 7 and 8. The Friday meeting was a joint meeting with the Mechanics Colloquium of Illinois Tech and the Illinois Section of the A. S. C. E. The dinner at 7 P.M. was attended by 300 persons and the evening lecture at 8:15 P.M. was attended by 400 persons. This lecture was presented by Professor Hardy Cross of Yale University who was until 1937 active as a member of the Illinois-Indiana Section. The dinner was an honorary banquet commemorating the 25th anniversary of the development of the Cross method of moment distribution.

At the meeting on Saturday, May 8, Dr. L. E. Grinter, Chairman of the Section, introduced President Henry T. Heald of Illinois Institute of Technology who spoke briefly on the development program of the Institute.

The program included a panel discussion on "The Broad Objectives of Engineering Education" by J. J. Cavanaugh, President of Notre Dame University; F. L. Hovde, President of Purdue University; D. B. Prentice, President of Rose Polytechnic Institute; H. T. Heald, President of Illinois Institute of Technology. J. D. Lohman of the University of Chicago was moderator.

The meetings in the afternoon included papers on the following subjects: Teaching Thermodynamics and Fluid Flow, Drawing in the Engineering Curriculum, Non-Technical Values in Engineering Education, Engineering Analysis in All Curricula, and Teaching Dynamics and Design.

The following rotation of meeting places was approved: University of Notre Dame, Purdue University, Northwestern University, University of Illinois, Rose Polytechnic Institute, Illinois Institute of Technology.

Officers elected for 1948–49 included Chairman, F. J. Schubmehl, University of Notre Dame; Vice Chairman, W. A. Knapp, Purdue University; Secretary, W. E. Drinkwater, University of Notre Dame; Council Representative, L. E. Grinter, Illinois Institute of Technology.

Application of Micro-pilot Plant Techniques to the Unit Operations Laboratory*

By W. M. LANGDON, W. W. SHUSTER, L. S. COONLEY, and H. C. OTT

Department of Chemical Engineering, Rensselaer Polytechnic Institute

Definition of Micro-pilot Plant

The term "micro-pilot plant" has been used in this paper to designate equipment, whose size is much smaller than that commercially available, yet larger than that of the laboratory. The amount of material either in process or being studied in a micro unit operation likewise is between that of the laboratory and pilot plant. Since this type of equipment is not available, it must be designed and built. It is agreed that these techniques can not be applied to all unit operations, but it it hoped that the discussion which follows will show the desirability of incorporating such procedures in unit operations laboratory and how it can be applied to distillation.

The customary method of conducting many phases of unit operations laboratory has been to assign from three to six hours for a laboratory period. During this time the students must put the equipment in operation, allow time for steady state to be attained, and make their measurements. The equipment used is either a small commercial unit or one built to commercial specifications and is usually suitable for the study of one operation only. The directions are given more or less completely so that the experiment may be completed in the given time. Too frequently the experiment is designed for the time available or to be run under conditions of low capacity because of the large amount of material required which can be hazardous, expensive or both. Because of its size and construction, it is frequently difficult to make wide changes in operating variables within the time allowed; hence a group has to spend many periods if a complete coverage of operating characteristics is to be covered. The cost of the equipment and its maintenance is high.

In the light of the philosophy that increased emphasis should be placed on basic and fundamental knowledge underlying engineering education, the above procedure does not appear to be conducive to the best attainment of this aim for the following reasons. When commercially available units are used to obtain some idea of industrial operations, the very size prevents the obtaining of definitive data. Batch or unsteady state experiments are arranged to fit the time and material available. Too much time is consumed in reaching steady state conditions. The choice of materials that can be used is limited. Finally, the various factors measured, because of the method of conducting the experiment, are out

* Presented at the Middle Atlantic Section Meeting, New York, December 6, 1947.

of focus for comparison with industrial conditions. The advantage left is a psychological one in that the student has worked with a piece of commercial equipment.

All this leads to the idea of scaling the equipment down many fold. While admittedly the data obtained may have no direct relationship to industrial operations, the scale-down gives a basic insight into the unit operation being considered. In small sizes, the important or controlling factors may be entirely different than in the case of larger equipment so that the equipment may have to be designed quite differently from the actual commercial unit. On a micro-pilot plant scale the setup can in many cases be made to run automatically for long periods of time during which the students can take periodic measurements. The amounts of material involved are small and hence there is little danger even if a hazardous chemical is used. Operating variables are readily changed. The time consumed in reaching steady state is not pertinent since the equipment can be run over a period of weeks, and the experiments can be performed concurrently with the theory course in unit operations. This will allow the student to take various data illustrative of the material being covered in the theory. The design, construction and operation of micro size equipment presents a challenge to the ingenuity and will require more mental effort in the devising of an experiment.

The above approach to unit operations has been under consideration for some time and in the belief that it is well worthwhile, such a program has been started. Distillation was chosen as the first unit operation to be developed using micro-pilot plant size equipment. The following is a description and discussion of the design and operation.

Distillation Experiment

The experiment will be run concurrently with the usual unit operations laboratory and will extend over a period of weeks with several squads participating. A separation problem will be assigned which will simulate some industrial operation. The problem will consist of three parts; (a) literature search, (b) operating calculations, and (c) experimental runs (including liquid-vapor equilibrium determinations) in the continuous micro column.

The design of a suitable column is described below. While the main features essential to the success of the column have been worked out [2, 11] some of the design factors are still not suitable for general laboratory use by students. In general, the column consists of two separate sections, each 1" × 4' insulated by electrical heating jackets [7, 8] with a central feed section. The column is supplied with a total vaporizer [5] and a total condenser and is controlled by reflux proportionators at the top and bottom of the column. The product streams are recycled by means of a total vaporizer back to the feed tank. Such a column will operate automatically with a minimum of control equipment. It will compensate automatically for small changes in column operation which is essential for its successful performance over an extended period of time.

The column is constructed of glass since experience has shown that visual inspection is a major factor in its successful operation. Glass is also one of the easiest materials with which to work without extensive equipment and is free of most corrosion difficulties. The column may be constructed so as

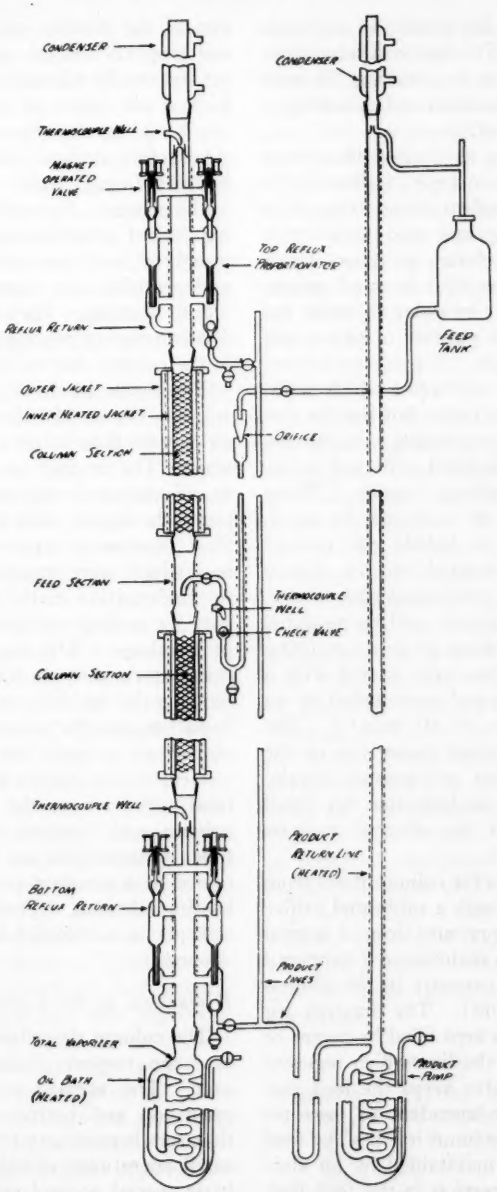
CONDENSER
CONDENSER
THERMOCOUPLE WELL
MAGNET OPERATED VALVE
TOP REFLUX PROPORTIONATOR
REFLUX RETURN
FEED TANK
OUTER JACKET
INNER HEATED JACKET
COLUMN SECTION
ORIFICE
FEED SECTION
THERMOCOUPLE WELL
CHECK VALVE
COLUMN SECTION
THERMOCOUPLE WELL
PRODUCT RETURN LINE (HEATED)
BOTTOM REFLUX RETURN
PRODUCT LINES
TOTAL VAPORIZER
OIL BATH (HEATED)
PRODUCT PUMP

FIG. 1.

to be free of all but accidental mechanical breakage. The latter disadvantage will be overcome by isolating the unit in a protected position and operating it by electrical controls.

The rectifying sections of the column will contain some type of plates both to give the student some idea of a commercial unit and also to allow a more positive column operation which will be less susceptible to small operational changes. In order to make the unit flexible the number of plates will be easily variable. A glass perforated plate [9] has been developed which simulates commercial plates but has the disadvantage of complicated construction when made in isolated units and is unstable with frothing liquids. These difficulties may be overcome by developing screen [3] or bubble cap plates [1] which may be inserted into the column similarly to the perforated glass plates.

The column proper will be insulated by electrical heating jackets consisting of a 45 mm. glass tube wound with a heating element and surrounded by an insulating tube of 60 mm.[7,8] The jackets allow visual inspection of the column operation and provide insulation otherwise unobtainable for small columns except by silvered vacuum jackets.[10]

Liquid feed to the column flows from a feed tank through a calibrated orifice across which a pressure drop of several feet of liquid is maintained (compared to a maximum pressure in the column of 2 feet of liquid). The pressure leg to the column is kept filled by means of a float valve in the line which together with a check valve keeps the feed rate constant and independent of pressure changes in the column itself. The feed temperature is maintained by an electrically heated section in the feed line.

Liquid streams from the top and bottom of the column will be withdrawn and proportioned into reflux and product streams by solenoid operated valves. Reflux will return to the column via a small hold-up chamber to ensure a constant reflux stream. This is important in maintaining steady state conditions in the column. Several types of swinging funnel proportionators have been tested [11,2] but have been found to be undependable for extended operation due to sticking. They have the added disadvantage of causing pressure surges in the column due to intermittent flow.

The top and bottom product streams will be taken off through lines provided with float valves serving as vapor traps. The product streams will be fed to an external vaporizer which will pump the liquids back to the feed tank. Past equipment employed barometric legs which were unsatisfactory due to to condensation in the long leg necessary for sealing, and due to the danger of breakage. The leg also was unsatisfactory due to the possibility of blowing the seal by a momentary surge from the column which necessitated a shut-down to reseal the leg.

Heat to the column is supplied by a total vaporizer at the bottom of the column and consists of an indented tube immersed in an oil bath maintained at a constant temperature by a heating element. Pumping of liquid streams is accomplished by a similar vaporizer.

Discussion of the Continuous Column

The column described above departs in some respects from an industrial unit. The method of control based upon top and bottom reflux proportionators is necessary to compensate for small operational changes and to eliminate special control equipment. This compensation is very important in a

small column as its lack of inertia would otherwise result in very erratic results. However, this does not detract from the fact that the column is operating strictly according to the principles of fractional distillation.

The authors' experience with the customary laboratory distillation column (6" diameter or larger) has been very unsatisfactory. The usual practice is to run the column either as a batch unit or as an enriching section by recycle of the product stream to the still pot.

Because of time restrictions the usual column is limited to a few plates and a system with a wide spread in boiling points is used. The results from a batch distillation in such cases are very qualitative and the steady state distillation calculations are in serious error.[1a] Steady state operation of an enriching section is also subject to limitation. In addition to varying the reflux ratios and still composition, the effect of compositions on plate efficiency is often measured by sampling the individual plates. The depletion of the more volatile component by the sampling should require a rather long wait between sampling which limits the number of possible measurements.

Also, when working with systems having a high relative volatility the values are very erratic even when measured with the utmost care.[4,6] The case where a column of few plates is used with a system of low relative volatility does not give very representative data as it must cover a very narrow composition range and there is no advantage in sampling all of the plates, since the efficiency is practically constant with composition. It does seem from a consideration of these factors that the best results can only be obtained by using many plates and operating on a system of low relative volatility. Since each run will require several days to approach steady state conditions, representative data will require the experiment to spread over a period of weeks.

The value of such columns is not confined to a unit operation laboratory. They can be used to separate automatically or analyze fractions which possess some distinct physical property for analytical control, usually boiling point.

Discussion

A number of other unit operations also seem adaptable to micro-pilot plant techniques. Gas absorption and solvent extraction can be handled in a manner similar to distillation except that it will probably be necessary to introduce new material at a controlled rate, since complete recycling of material is here not readily achieved. It should also be possible to apply several complementary operations, such as grinding, elutriation, settling and filtration to the same problem. The principles of evaporation can be studied as effectively in small glass equipment as in a commercial unit. Fluid flow and heat transfer may be studied in parts of equipment designed primarily for some other operation.

It is felt that a unit operations laboratory conducted along these lines will give students a better insight into the principles underlying the various operations.

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Sections

The annual meeting of the **Rocky Mountain Section** was held Saturday, May 1, on the Colorado A. & M. Campus. Principal speakers in the morning session included I. E. Newsom, President of Colorado A. & M. College, and C. M. Knudson, Dean of the University of Denver. Papers were presented on subjects dealing with Prediction of Academic Success, Pre-Engineering Inventory Examinations, A New Approach to Engineering Mechanics, and Engineering Implications of the President's Commission on Higher Education.

More than 200 members and guests of A.S.E.E. and the student branches of A.S.C.E. attended the luncheon at which Colonel W. N. Carey, National Secretary, A.S.C.E., gave a very stimulating address.

Retiring Chairman, J. T. Strate, presided over the business meeting at which the following officers were elected: J. W. Greene, Chairman, and Martin Capp, Secretary, for the year 1948–49; N. A. Christensen, Colorado A. & M. College, Council representative.

The Section gladly accepted Denver University's invitation to meet in Denver next year. The section voted to invite Utah University and Utah State A. & M. to join this Section.

Teaching Coriolis' Law*

By A. S. HALL

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Introduction

A primary goal of undergraduate engineering instruction is to provide the student with the fundamentals of the art, to equip him with concepts and techniques which will serve as a firm basis for continuing development of his technical abilities. It is the author's belief that we are falling short of this goal in our teaching of kinematics if we fail to present in a clear light the relation known as Coriolis' law of acceleration.

The majority of textbooks in the English language teach the construction of the acceleration polygon, image, or phorograph. "Acceleration polygon" will be used here to refer to all of these constructions. Construction of the acceleration polygon involves the solution of a series of vector equations relating the accelerations of pairs of points of the mechanism. These equations are of the form

$$A_p = A_q \mapsto A_{pq}. \tag{1}$$

The term A_{pq} is usually referred to as "the acceleration of P relative to Q." Expression (1) may be regarded as a definition of the relative acceleration of two points. In words "the acceleration of P relative to Q is that which must be added to the acceleration of Q to obtain as a result the acceleration of P." In general P and Q may be any two points, of the same or different links, coincident or separated. In practice two cases are found to be of special importance.

Case I. In this case P and Q are two points of the same rigid link for which we show the relation

$$A_{pq} = A^n{}_{pq} \mapsto A^t{}_{pq}, \tag{2}$$

where

$$A^n{}_{pq} = \overline{PQ}\omega^2 = (V_{pq})^2/\overline{PQ} \tag{3}$$

and

$$A^t{}_{pq} = dV_{pq}/dt = \overline{PQ}\alpha. \tag{4}$$

The component $A^n{}_{pq}$ is shown to be directed from P toward Q and the component $A^t{}_{pq}$ normal to the line PQ. ω and α are respectively the absolute angular velocity and angular acceleration of the link containing points P and Q. The above relations suffice for the analysis of pin-jointed linkages and those which may be reduced to equivalent pin-jointed linkages. It has been the author's experience that the average student in his sixth semester has little difficulty following a proof of the above relations and readily becomes proficient in their use. Having previously encountered the expressions $R\omega^2$ and $R\alpha$ for rotation about a fixed center he is prepared to accept intuitively the validity of relations (2), (3) and (4).

Case II. This is the situation covered by Coriolis' law. P and Q are two *coincident* points of *different* links.

* Presented at the Annual Meeting, Minneapolis, June 14–18, 1947.

The relation for A_{pq} in its most convenient form for calculations is

$$A_{pq} = A^t{}_{pq} + a^n{}_{pq} + 2V_{pq}\omega, \quad (5)$$

where

$$A^t{}_{pq} = dV_{pq}/dt \quad (6)$$

and

$$a^n{}_{pq} = (V_{pq})^2/R. \quad (7)$$

R is the radius of curvature of the path traced by P on the body containing Q. The component $a^n{}_{pq}$ is shown to be directed from P toward the center of curvature of the path and the component $A^t{}_{pq}$ parallel to V_{pq} (tangent to the path). The component $2V_{pq}\omega$, known as "Coriolis' component" or the "compound supplementary acceleration," is normal to the path, with a sense dependent on the senses of V_{pq} and ω.

Should instruction not be carried beyond Case I the student is left in a position where he is incapable of constructing the acceleration polygon for some of the most common mechanisms. More serious is the fact that he does not *realize* the lack. His intuition will wrongfully lead him to apply to Case II the relations for Case I, with the substitution of R for PQ. To avoid this almost certain error some treatment of Case II appears absolutely necessary. The better treatments will include a derivation readily followed by the student.

Possible Derivations of Coriolis' Law

A variety of derivations of Coriolis' law have been offered in texts and in the periodical technical literature. These might be grouped as follows.

(1) ***Derivations in which acceleration components are determined from a consideration of the velocity changes taking place.***

This type of derivation in its more formal and rigorous form involves considering the vector change in relative velocity, ΔV_{pq}, which takes place during a small time interval, Δt, and obtaining the relative acceleration, A_{pq}, as the limit of $\Delta V_{pq}/\Delta t$ when Δt approaches zero. A less rigorous form involves noting all the elements of the motion contributing to changes in direction or magnitude of the velocity and writing the resulting acceleration components directly.

Even when presented carefully and slowly by the instructor these derivations require a high degree of concentration on the part of the student. They are not readily reproduced by the average student. Errors easily creep in through the omission of one or more components of velocity change.

(2) ***Derivations in which the position of the moving point is expressed in rectangular coordinates and the acceleration expression obtained by differentiation.***

Derivations of this type may be general, treating the case of a point moving on any path in plane motion, or may be limited to the case of a point moving on a straight path as that path rotates about a fixed center at the origin of the coordinate system. The latter treatment is found more frequently than the former in kinematics texts. Derivations of this type are rather long but are rigorous and require little imagination to carry through once the displacement relations are set up. A disadvantage is the necessity for converting from X and Y components to normal and tangential components.

(3) ***Derivations in which the positions of the points involved are expressed as vectors in the notation "$Re^{i\theta}$" and***

the acceleration relation obtained by differentiation.

This is a neat way of handling all velocity and acceleration derivations but has not been used in any kinematics text with which the author is familiar. Our students usually do not become acquainted with the notation until they study alternating current electricity. A strong argument might be developed for using the notation in kinematics if for no other reason than to impress on the student the fact that all fields of engineering and science make use of the same tools.

(4) *Derivations making use of an "equivalent link."*

The idea behind this treatment is based on the fact that, for the purpose of computing velocities and accelerations, a point tracing a path on a body may at a particular instant be treated as though carried by a rigid link pin-jointed to the body at the center of curvature of the path corresponding to the instantaneous position considered. Recognition of this makes it possible to derive Coriolis' law directly from the expression for the relative acceleration of two points of a rigid link. This treatment does not appear in the latest editions of any texts with which the author is acquainted. It did appear in the fifth edition of "Elements of Mechanism," by Schwamb, Merrill and James and was also used by Professor P. K. Slaymaker in his excellent article "How to Determine Accelerations . . .," *Machine Design*, July, 1946.

The author feels that a derivation of this nature is the simplest, shortest and most readily grasped. It makes maximum use of the students' previous knowledge and shows clearly the connection between Case I and Case II, eliminating much of the mystery which seems to have associated with Coriolis' component. A possible sequence of steps in presenting the law to the student is outlined in the next section.

Equivalent Link Derivation

It is assumed that the student is already thoroughly familiar with the expression for the relative acceleration of two points of the same rigid link. Figure 1 illustrates the relation for points P and C of link X. ω_x and α_x are respectively the absolute angular velocity and angular acceleration of link X. The case is general for plane motion; no center of rotation is specified.

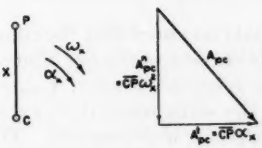

FIG. 1

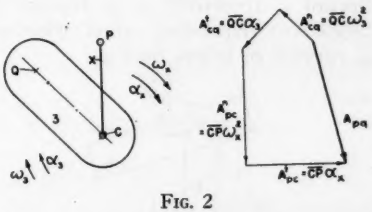

FIG. 2

Figure 2 shows link X pin-jointed to a body, 3, at point C. The polygon illustrates the relation

$$A_{pq} = A_{cq} + A_{pc}. \qquad (8)$$

Point Q is taken such that distance $\overline{CQ}$ is equal to distance $\overline{CP}$.

Figure 3 shows link X and body 3 in relative position such that Q and P are coincident. The acceleration polygon again illustrates the relation, $A_{pq} = A_{cq} + A_{pc}$. A_{pq} is resolved into

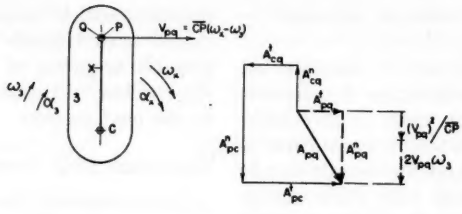

FIG. 3

two components, A^t_{pq} directed normal to line CP and A^n_{pq} directed parallel to line CP. The student should readily see the relations,

$$A^t_{pq} = \overline{CP}(\alpha_x - \alpha_3) \qquad (9)$$

and

$$A^n_{pq} = \overline{CP}(\omega^2_x - \omega^2_3). \qquad (10)$$

It should be noted that the component A^t_{pq} is the rate of change of magnitude of the relative velocity, V_{pq}, and will have the same sense if V_{pq} is increasing, opposite if decreasing. The component A^n_{pq} will have the sense P toward C (positive) or C toward P (negative) depending upon whether ω_x exceeds or is less than ω_3.

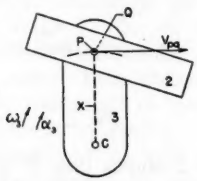

FIG. 4

It might next be pointed out that it is convenient to have the component A^n_{pq} expressed in terms of V_{pq}. Furthermore, since the expression $\overline{CP}(\omega^2_x - \omega^2_3)$ becomes indeterminate when $\overline{CP}$ becomes infinite, (10) is not usable for the important case where X is a slider having rectilinear motion relative to 3. Therefore we make the following rearrangement:

$$(\omega_x^2 - \omega_3^2) = (\omega_x - \omega_3)^2 + 2\omega_x\omega_3 - 2\omega_3^2$$
$$= (\omega_x - \omega_3)^2 + 2(\omega_x - \omega_3)\omega_3 \qquad (11)$$

But

$$\overline{CP}(\omega_x - \omega_3) = V_{pq}. \qquad (12)$$

Hence (10) becomes

$$A^n_{pq} = (V_{pq})^2/\overline{CP} + 2V_{pq}\omega_3. \qquad (13)$$

Inspection of the figures and the above relations will show that the component $(V_{pq})^2/\overline{CP}$ is always positive (sense P toward C). Coriolis' component, $2V_{pq}\omega_3$, will be positive when $(\omega_x - \omega_3)$ and ω_3 have the same sense and negative when they have the opposite sense. From this may be developed the rule illustrated in Fig. 5

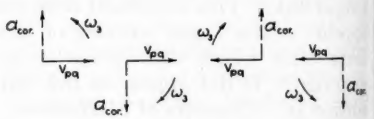

FIG. 5

—"The sense of Coriolis' component, $2V_{pq}\omega_3$, is the sense of the relative velocity vector, V_{pq}, rotated 90 deg. in the sense of ω_3." It might not be amiss, if it has not already been done, to point out to the student that this rule applies to any acceleration component of the form $V\omega$.

To extend the derivation to the general case for plane motion, in which

P traces any path on body 3 consider Fig. 4. P is a point of body 2 tracing on body 3 a path which, for the position shown, has center of curvature at C. As far as instantaneous velocities and accelerations are concerned this case may be treated as though a rigid link, X, were pin-jointed to body 2 at point P and to body 3 at point C. If Q be the point of 3 coincident with P then the acceleration relation, directly from the previous result, is

$$A_{pq}=A^{t}_{pq}+(V_{pq})^2/\overline{CP}+2V_{pq}\omega_3. \quad (14)$$

It has been implied in several texts that the "equivalent link" may be used only if the path is a circle arc. This may be the reason for not using the above treatment more widely. The difficulty may lie in a failure to distinguish between the varying radius of curvature of the path and the varying radius vector which coincides with the radius of curvature only for the instantaneous position considered. Figure 6 illustrates the distinction.

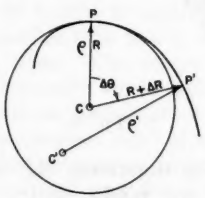

FIG. 6

R is the radius vector with origin at the center of curvature corresponding to point P of the curve. The radius of curvature is ρ. It is not ρ but R, with its first and second derivatives, which enters velocity and acceleration expressions. Since $dR/d\theta$ and $d^2R/d\theta^2$ are both zero at the position in which R coincides with ρ a point would have the same instantaneous velocity and acceleration in that position whether considered as moving on the path with varying radius of curvature or on the circle of radius R. The third derivative of R with respect to θ is not zero in general; therefore the "equivalent link" treatment could not be used to investigate rate of change of acceleration.

A similar situation exists in our treatment of velocities by the instantaneous center method. There we compute the velocity of a point as though it were carried by a rigid link pin-jointed at a point on the normal to the path of the point. The fact that this point (the instantaneous center) is not the center of curvature of the path, or even that it might not lie on the same side of the path as the center of curvature, does not invalidate the procedure. Only the first derivative of R enters a velocity computation and this is zero for any origin on a normal to the path. The instantaneous center of velocities cannot be treated as a center of rotation for computing accelerations, however, because the second eerivative fo R enters the acceleration expressions and is zero only if the origin is at the center of curvature of the point path.

Applications and Problems.

The experienced instructor realizes that any formal law gains in significance and is more easily remembered when connected with common or readily imagined personal experience, observable physical phenomena and applications outside the immediate field of study. An imaginary rotating skating rink was described by Professor E. S. Ault and the author to convey a physical picture of the significance of Coriolis' component in an article "How Acceleration Analysis Can Be Improved," *Machine Design*,

February, 1943. The forces to which one would be subject when skating radially or circularly are readily visualized and can be explained in terms of Coriolis' law. Explanation of the opposite rotation of cyclones in the Northern and Southern Hemispheres never fails to create interest. Forces developed in the fluid coupling are explainable in terms of Coriolis' law and furnish a good example of practical interest to the engineering student but outside the immediate field of rigid body kinematics. Other interesting applications will occur to the resourceful instructor. Without doubt many have been used by readers of this paper. Sharing of our ideas along this and other lines will contribute to the more effective teaching of all.

Suitably chosen problem work for the student is, of course, of great importance. In view of ever present time limitations the problems must be selected carefully for maximum effect. The first problem assigned might well involve a simple device for which the acceleration polygon could be constructed either with or without the use of Coriolis' law. The student's confidence will be increased if he makes the solution both ways and observes the same results. The flywheel governor of Fig. 7 illustrates this type of problem.

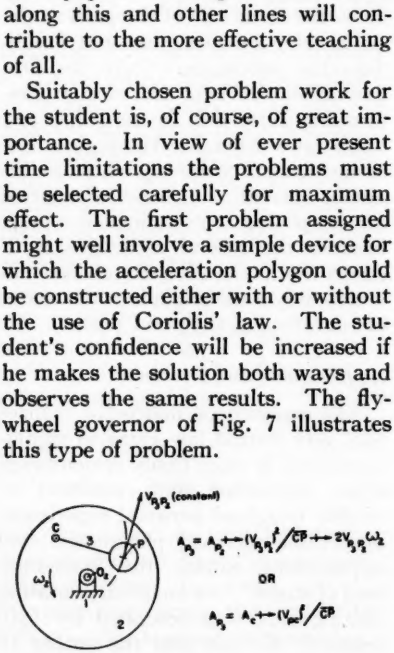

FIG. 7

The second problem might involve a simple mechanism for which no convenient method of solution is available other than the use of Coriolos' law. This is illustrated by the tangent cam with oscillating roller follower in Fig. 8.

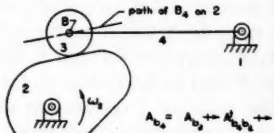

FIG. 8

The third problem might introduce the idea of rearranging the acceleration vector equation for the frequently encountered situation in which the point whose acceleration is desired does not trace an obvious path. Thus for the crank and slotted link mechanism of Fig. 9, if the motion of crank 2 is known and it is

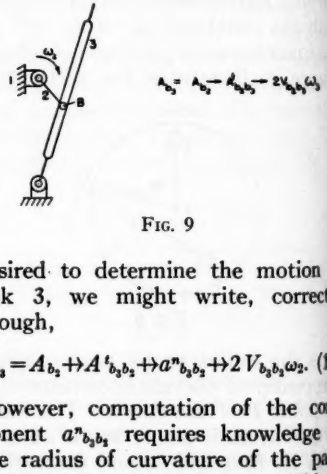

FIG. 9

desired to determine the motion of link 3, we might write, correctly enough,

$$A_{b_3} = A_{b_2} + A^t_{b_3b_2} + a^n_{b_3b_2} + 2V_{b_3b_2}\omega_2. \quad (15)$$

However, computation of the component $a^n_{b_3b_2}$ requires knowledge of the radius of curvature of the path which B_3 traces on link 2. This is not readily apparent. On the other hand the path traced by B_2 on link 3 is obviously the center line of the slot. Hence a more convenient solution is obtained by writing the acceleration

equation first as though solving for the acceleration of B_2.

$$A_{b_2} = A_{b_3} + A^t_{b_2 b_3} + 2V_{b_2 b_3}\omega_3. \quad (16)$$

Expression (16) may be left in this form or rearranged with A_{b_3} on the left side of the equation, whichever the student finds the easier to follow in constructing the vector diagram.

Additional problem work, involving more complicated mechanisms, might be assigned as time permits. Three problems, similar to those suggested above, are about the minimum the student should solve before he can be assumed to have a reasonable grasp on the subject.

Conclusion.

If we are to teach acceleration analysis at all in our undergraduate kinematics courses Coriolis' law should be included. Complete omission of this law leaves the student in a position where his intuition will lead him to erroneous solutions. That Coriolis' law can be taught to undergraduates in a reasonable time is the conviction of the author. The major requirement, a derivation which is simple and easy to follow, seems to be satisfied by the "equivalent link" idea. If the student has previously mastered the acceleration polygon for pin-jointed linkages it should be possible to cover Coriolis' law adequately with one hour of lecture and three hours of problem work.

APPENDIX

References on Derivation of Coriolis' Law

The following is a partial list of references which offer a derivation of Coriolis' law. The type of derivation is indicated at the right by numbers corresponding to the grouping in the body of the paper.

1. "How to Determine Accelerations . . .," by Slaymaker, *Machine Design*, July, 1946, pp. 147–150 (4)
2. "Engineering Kinematics," by Sloane, Macmillan, 1945, pp. 296–299 (2)
3. "Mechanics for Engineers," by Maurer, Roark and Washa, John Wiley, 1945, pp. 192–197 (1)
4. "Mechanism," by Prageman, International Textbook, 1943, pp. 281–283 (1)
5. "Applied Kinematics," by Billings, D. Van Nostrand, second edition, 1943, pp. 109–111
6. "How Acceleration Analysis Can Be Improved," by Hall and Ault, *Machine Design*, Feb., 1943, pp. 100–102, 162, 164 (3)
7. "Analytical Mechanics for Engineers," by Seely and Ensign, John Wiley, third edition, 1941, pp. 391–394 (1)
8. "Mechanism and the Kinematics of Machines," by Steeds, Longmans, Green and Co., 1940, pp. 27–31, 101–104 (2), (1)
9. "Engineering Mechanics," by Timoshenko and Young, McGraw-Hill, second edition, 1940, pp. 476–479 (2)
10. "The Theory of Machines," by Bevan, Longmans, Green and Co., 1939, pp. 86–90 (1), (2)
11. "Elements of Mechanism," by Schwamb, Merrill and James, John Wiley, fifth edition, 1938, pp. 84–87 (4)
12. "Mechanics of Machinery," by Ham and Crane, McGraw-Hill, 1938, pp. 292–298 (1)
13. "Kinematics of Machinery," by Albert and Rogers, John Wiley, 1938, pp. 105–109 (1)
14. "Theory of Machines," by Toft and Kersey, Pitman, third edition, 1937, pp. 14–15 (2)
15. "Kinematics and Kinetics of Machinery," by Dent and Harper, John Wiley, 1921, pp. 89–93 (1)

DISCUSSION

E. M. Griswold, Cooper Union:

I like your presentation because it is based upon a physical concept rather than purely mathematical operations. My experience in teaching kinematics has indicated that the material is grasped more readily by most students if a principle can be demonstrated by the use of a physical concept, either with or without a mathematical analysis, than with pure mathematics alone.

I have used derivations of Coriolis' law "in which the acceleration components are determined from a consideration of the velocity changes taking place" and "in which the position of the moving point is expressed in rectangular coordinates and the acceleration expression obtained by differentiation" but have not been satisfied with the results obtained. To the student it seems to be more of an exercise in mathematics than the demonstration of an important principal. The student then has difficulty applying the law to a specific case.

I am looking forward to trying the "equivalent link" derivation with my next class in kinematics. I think this may solve my problem.

I. W. Smith, University of Toronto:

That the Coriolis' supplement should be included in the kinematics course along with the teaching of the acceleration polygon is a point that cannot be disputed and I believe most textbooks recognize this fact by including not only the law but its proof as well. However, I feel that it is the application that should be given in the kinematics course and that the derivation more properly belongs in the dynamics course.

The equivalent link method of derivation is very well presented in your paper and appears to be reasonably brief. I have not taught this method but it seems on the surface to lack somewhat in straightforwardness. However, it has the advantage of stressing the coincident point principle, which should be of great help to students in kinematics.

At Toronto, Coriolis' law is taken up in a dynamics course common to second year students in Engineering Physics, Engineering Business, Civil, Electrical, and Mechanical Engineering. Since of these branches only the mechanicals have kinematics, there is not an adequate foundation for use of the equivalent link method.

The third method of derivation, by vector notation, is very neat indeed, but as you point out, it cannot be used until vector notation has been covered. At Toronto, the second year aeronautical engineering students have a dynamics course in which vector notation is taught so that the Coriolis' component falls out automatically.

The second method of derivation, by differentiation of X and Y coordinates, is quite good mathematically and can be sufficiently concise. However, I feel that it does not give the student an *understanding* of the Coriolis' acceleration nor is it an adequate preparation for the solving of actual problems.

Thus it is the first of the methods given in your paper that we use at Toronto. It is taken up as changes in magnitude and direction of two velocity vectors belonging to a point moving along a path that has rotation. It is true that this procedure requires greater teaching time—I use

three one-hour lecture periods, including actual examples involving straight and curved paths—but I believe the student has a better visualization of the accelerations. There is also the advantage that the rule given in your paper for the direction and sense of the Coriolis' component is directly obtained when rotation of the path velocity vector is considered. The results of this derivation are used later in the dynamics course for setting up the forces causing stress in a disc subjected to gyroscopic action.

The acceleration polygon is presented to our mechanical engineering students in the second year kinematics course that runs concurrently with the dynamics course. One lecture is given to the solution of a complete shaper mechanism, which of course includes the Coriolis' acceleration. Later in the course, when cams are discussed, the polygon for an arc and tangent cam is worked out and compared to a purely mathematical solution.

In the drafting room the second year students do one three-hour problem requiring Coriolis' acceleration. Last year the problem was a complete velocity and acceleration analysis of the Pratt and Whitney vertical shaper. On this problem they seemed to have an excellent grasp of the required solution and I am wondering if it is not better to spend more time in teaching the fundamental approach than to rely on a variety of laboratory exercises for full mastery of the method.

Electrical Engineering Laboratory Exercises

By JOSEPH C. MICHALOWICZ

Assistant Professor of Electrical Engineering, Catholic University of America

Among the many problems confronting the small engineering university, in these days of overcrowded conditions, is the method of presenting laboratory exercises to electrical engineering students. The laboratory instructor found it sufficient for his small, prewar classes, to personally outline the exercises on a blackboard or to issue to the student brief mimeographed notes. Unfortunately, this procedure is no longer feasible. Either very detailed exercises must be prepared by the instructor himself or a printed laboratory manual-text must be adopted. Both have their obvious advantages and disadvantages.

In order to determine the general trend among engineering schools, a survey, entitled "Laboratory Manual Survey" was conducted by the author. Questionnaires were sent to 120 schools having E.C.P.D.-approved programs in electrical engineering, asking questions concerning both the personally prepared laboratory exercises and the printed laboratory manual-text. Answers were received from 90 schools, at the time of this writing, and the following results were based on these replies.

The table below shows the percentage of the schools using personally prepared forms, such as mimeographed or lithographed outlines. The figures in parentheses indicate the number of schools, out of the 90 schools answering, that offer the course considered.

Type of course	*Percentage using personally prepared exercises*
D–C Circuits and Machinery	88% (90)
A–C Circuits and Machinery	83% (90)
Electronics	90% (89)
Communication	92% (83)
Other (such as Illumination, Measurements, E.E. for non-E.E.)	90% (49)

Of these schools, approximately 10 per cent indicated that the printed manual-text was used as a supplementary reference and guide.

Of the schools indicating sole use of the printed manual-text, the following publications were the most popular.

A-C and D-C circuits and machinery: Dennison-Karapetoff, "Electrical Laboratory Experiments," John Wiley & Sons; Reed and Corcoran, "Electrical Engineering Experiments," John Wiley and Sons; Hehre and Blamford, "Electric Circuit and Machine Experiments," John Wiley and Sons.

Electronics and communications: Schulz and Anderson, "Experiments in Electronics and Communication Engineering," Harper and Bros.

E.E. Lab. for non-E.E. students: Beck, "Electrical Engineering Laboratory Manual," Tri-State Offset Co.

But even these users of the printed manual-text indicated dissatisfaction with the material, since about 60 per cent stated that these manuals were inadequate for their means. The reason for the inadequacy of these manuals was expressed unanimously as not being readily adaptable to available equipment or the particular instructor's interests.

Some of the comments made concerning the printed manual-text are worthy of note.

"Equipment, procedures and philosophy are so different that only your own manual written for your own institution will serve your needs adequately."

"Published laboratory manuals are not suitable for large well-equipped schools which are continually changing experiments."

"Many published manuals do not seem to be written at a high enough level for 3rd and 4th year students."

"Each teacher wants to write his own manual."

"Printed manuals do not permit a ready change . . . changing experiments discourages building up fraternity libraries."

"Printed manuals do not allow instructors any freedom or field to try his ingenuity."

"Printed manuals OK for the man who prepared them."

A Boomerang in Grading Engineering Drawing Problems

By MYRON C. BISHOP

Associate Professor of Engineering, Evansville College

For many years there has been a growing tendency to evolve a method to hasten the grading of Technical Drawing problems. Instructors become impatient having to spend long hours trying to arrive at what is considered a fair and just grade on hundreds of drawing problems. An increase in the number of sections, as well as the number of students in a section, shows a definite up-trend since the sudden go-to-college urge has become prevalent among veterans. Many instructors in colleges and universities, particularly in our larger engineering schools, find themselves trying to teach Technical Drawing and Descriptive Geometry with a shortage of texts, tables, and a minimum of working tools. There appear to be only a few schools which have the administrative courage to screen their students and thus keep enrollments within the scope of maximum capacity. It would certainly seem more fair to ask a student to wait a semester or two, rather than herd him into a large group where he seldom knows even the names of his instructors. One may just as well engage in a correspondence course as to enter into the congested conditions that exist in many of our engineering schools.

During the life of the V-12, V-7 and the ESMWT programs, instructors took advantage of what had previously been done by way of short cuts for grading drawings. Work books were used to enable all to get the same background and to enable the inefficient teacher to have a corrected set of problems by which to check all the students' work sheets. This brought forth new and quicker devices for checking problems. One such device was as follows: A metal frame was constructed whereby a drawing could be placed in a definite position with a correct tracing placed on top. This enabled the instructor to see at a glance where lines had been placed incorrectly on a drawing. The instructor, or checker, as one should be called, who does this type of work, counts the number of lines that are incorrectly placed in order to establish a grade. Each sheet carries a number and the student is dealt with on all occasions by the number. He is only a number and he passes or fails the work by that given number and by the number of lines he places out of position on his sheet. Let me cite an example. A graduate engineer kept failing on all the drawings he handed in for an engineering drawing course. Upon investigation it was found that by trimming the border line he had been shifting the position of the drawings one fourth inch and thus making them out of line for the master key. When he became aware of the cause of

the trouble he approached the professor whose defense was that had the student been more careful about following directions it would not have happened.

Several hours are necessary to teach a new instructor how to use a cross section computation grade chart. By actual visitation of several schools that use an elaborate system of grading computation it has been observed that the instructors are seldom seen in the classroom, but spend their time computing grades of problems already completed. It may be an antiquated idea but it is still the opinion of some that time spent in direct contact with students in the classroom is of far greater value than as the human element in a grading machine.

Faithful followers of mechanical checking devices have not yet attained Utopia. Why not design a machine similar to an automat in which the student could deposit a coin and receive the assigned problem for that day? Then at the end of the laboratory period could he not insert the finished drawing again into the machine and receive a grade? This system might be of some merit were there nothing more to be gained than the one variable. An objective test, such as one on projection, could be run through on a checking machine, but it could not check the many variables that go to mark progress in drawing technique. If a mechanical means of checking drawings is considered the best way of judging progress in technical drawing then a teacher can find very little excuse for existence; student helpers can feed the machines with just as much efficiency.

It is not deemed necessary to delve into the characteristics of a superior or a poor instructor except to say that the characteristics of a good instructor cannot be incorporated into a mechanical device. A superior teacher has something that cannot be readily defined or measured, call it ability or personality or what you will. The best means of securing maximum results differs with each teacher.

Personnel directors of three industries, each of which employs over six thousand people, have expressed the opinion that our present-day graduate engineers lack the ability to sell themselves, have very little regard for the rights of others, and assume that industry owes them a living on somewhat the same basis as in college life where father footed the bill. These same individuals, if employed, expect raises on time spent rather than ability and willingness to be of worthwhile service to the company. This appalling attitude is not entirely due to the educational system nor to the home background but has been brought on more by the abnormal economic situation. Nevertheless it remains the task for all engineering schools to remedy these deficiencies in so far as it is possible. Should the present trend continue, the time will soon come when there will be no backlog of engineers who choose to do creative thinking and who are willing to weld their college training into a working machine.

Some engineers in the teaching field are beginning to discuss the over supply of people who will be entering the profession within the next five to ten years. They propose to reduce the number of graduates by means of technical tests for freshmen. Business and industry are always in need of people who are willing to work and assume responsibility, and who can cooperate with and inspire others. These traits do not come about by memorizing technically proven facts only. We should not have

mass college instruction in large classes. It is far better to have small classes taught by one who has a broad general knowledge as well as a specific interest in order that he may better understand and cope with the particular problems and situations of the individual student. Certainly a college instructor should be well versed in guidance to avoid putting a square peg in a round hole. The gap that has been growing between industry, business, and our college students must be bridged by a closer relationship and ways and means of understanding one another. The gap can be lessened by the enrichment of the students' experiences. This can be accomplished, in part at least, in the drawing laboratory by the instructor's presence where he can move about and instill his knowledge as he goes.

Summary

Some of the unit operations, if scaled down to micro size, could be run continuously over a period of weeks. The small size permits a flexible, economical and safe study of the underlying principles of the unit operation. While the design factors will not be industrially applicable the same is true of the usual equipment due to the limitations of size and the nature of the batch operation.

This philosophy is being applied to distillation. A continuous laboratory column has been developed which will operate automatically for long periods on liquid charges as small as 1 liter. The column proper is constructed in two sections, each 1″ I.D. by 4′ long which can be supplied with up to thirty-five perforated plates. Control is obtained by employing a total vaporizer and condenser with top and bottom reflux proportionators. Product streams are recycled to the feed tank by a total vaporizer. No special controls are used since the column operation is self adjusting.

Similar techniques are being contemplated for absorption, evaporation, grinding, filtration and extraction.

Meeting of the Executive Board

A meeting of the Executive Board of the A.S.E.E. was held at Northwestern University, Evanston, Illinois, April 24, 1948. Those in attendance were: C. E. MacQuigg, *President,* F. M. Dawson, C. J. Freund, B. J. Robertson, S. S. Steinberg, J. S. Thompson, A. B. Bronwell, Nell McKenry, and Dorothy Isebrands. The following items were considered and the actions indicated taken:

1. Report of the Secretary. Secretary Bronwell reported on the work in his office this year. In addition to the routine business of the Society, the Secretary's Office has:

a. assisted the President in conducting a membership drive which has resulted in 958 new members.

b. made a careful cross-check of the alphabetical and geographical listings in the *Yearbook* in order to provide accurate mailing lists for use of the Sections.

c. prepared an Office Procedures Manual for the handling of office matters including membership, dues, advertising, publication, accounting procedures, trust funds, committees, divisions, sections, etc.

d. solicited additional advertising for the JOURNAL.

2. The Treasurer, J. S. Thompson, made a report on the finances of the Society to date and suggested certain changes in the present accounting system. The Board approved these suggestions and also a motion that secretarial salaries be included under administrative expenses.

The Treasurer was requested to ascertain whether or not some of the restricted funds of the Society could be invested in government bonds.

The Treasurer recommended that the dues income be broken down into individual and institutional dues. He also recommended that the auditor's certification be published along with the annual Treasurer's Report in the September issue of the JOURNAL.

3. F. M. Dawson, Vice-President, presented a report of some of the activities of the ECRC:

a. Transfer of funds ($2,333.38) to the Society.

b. Approximately $201.00 income from sale of Directories has been paid to the treasury of the Society exclusive of the first item.

c. Bill H.R. 6007 (National Science Foundation Act of 1948) was discussed, and the recommendation of A. A. Potter as a member of the Science Foundation was approved.

d. Submitted a preliminary draft of amendments to the By-Laws of the ECRC.

4. S. S. Steinberg, Vice-President, presented a report of some of the activities of the ECAC.

a. Committee on Secondary Schools has been reorganized with L. M. K. Boelter as Chairman.

b. The survey of engineering salaries is being continued.

c. A campaign is being planned to secure additional institutional members, with particular emphasis on industrial organizations.

d. Amendments in the by-laws of the ECAC are being studied.

5. A proposed budget for 1948–49 was discussed. The Treasurer pointed out that the revenue per member is considerably smaller than that of other engineering societies. It was pointed out that the A.S.E.E. is basically a different kind of organization and should not attempt to pattern its finances after those of other national engineering societies. However, additional revenue probably can be derived from increased advertising.

It was voted to allocate $300.00 to the Engineering Drawing Division to assist the project of Unit Tests in Engineering Drawing now being developed.

The 1948–49 budget was tentatively approved by the Executive Board but is to be held over until the Board meeting in Austin for final action.

6. C. J. Freund discussed the fact that the Vice-President in charge of instructional and divisional activities spends too much time in preparation of material for the program of the annual meeting and suggested that the Society revise this procedure so that this Vice-President would have time to carry on more constructive work for the Society. A complete report of his recommendations will be published in the JOURNAL. A motion was passed that the Secretary's office organize the program of the Annual Convention.

7. The advisability of the Society's undertaking certain long-range projects was discussed. The projects considered included a study of teaching techniques and the improvement of teaching methods, the construction of audio-visual aids for basic science and engineering courses, and the sponsorship of summer schools. These projects will be considered further at the meeting of the General Council.

8. The report of the Publication Committee recommending the following increase in subscription rates, necessitated by increased publication costs, was approved:

	Present	Proposed
Subscription to JOURNAL (non-member)	$3.00	$4.00
Proceedings (individual members)	2.00	3.00
Proceedings (non-members)	3.00	4.00
Individual copies of JOURNAL	.50	.75
Yearbook (Transportation Companies)	1.00	2.00

This will be presented to the General Council.

9a. The advisability of including faculty placement advertisements in the JOURNAL was discussed and referred to the General Council for action.

b. Motion was made to refer to the General Council the matter of publishing the *Yearbook* once every two years, with the understanding that if this is done, a list of names and addresses of officers and committee members would be published each year in the JOURNAL. This would make it possible to publish an issue of the JOURNAL in place of the *Yearbook*, thereby providing an outlet for more papers, and effect a saving of approximately $1000 in the alternate years.

10. Applications of the Committee on Engineering Libraries and the Committee on Relations with Industry for division status were referred to the General Council for action.

11. The application of The Aeronautical University for affiliate membership was approved on the basis of technical institute accreditation only. The Secretary was authorized to accept their application upon receipt of a letter of application to this effect.

12. A resolution to the University of Pittsburgh was approved. It will be presented at the Annual Meeting.

13. The Executive Board approved a Committee on International Relations, with the following members: H. O. Croft, chairman, S. S. Steinberg, J. S. Thompson, and W. R. Woolrich.

14. F. M. Dawson was appointed to represent the A.S.E.E. on the National Research Council for a term of three years.

15. President MacQuigg read a letter which had been prepared to be sent to Mr. Day regarding the attitude of the A.S.E.E. on the proposed science legislation. The Executive Board voted approval.

Respectfully submitted,
A. B. BRONWELL, *Secretary*

Inter-Professions Conference

The Inter-Professions Conference on Education for Professional Responsibility, held in The Inn, Buck Hill Falls, Pennsylvania, April 12–14, was attended by many leading engineering educators.

The Conference, a meeting of 96 educators from the five professional fields of law, medicine, divinity, business and engineering, was sponsored by the Carnegie Corporation of New York to provide an opportunity for the different professions to assist each other by telling of their experiences in the effort to establish educational programs which would graduate "not only competent practitioners but good citizens and better men and women as well."

Each of the professions represented presented their viewpoint on:

1. What the goals and aims of professional schools should be.

2. What types of courses must be included and how can these courses be taught in order to give our professional men and women (a) the best possible start in learning their professions from experience and (b) the qualities which citizenship in an enduring free society demands of its leaders.

Speakers representing the engineering profession included Karl T. Compton, President of M. I. T., Robert E. Doherty, President of Carnegie Institute of Technology, and Harry S. Rogers, President of The Polytechnic Institute of Brooklyn.

Elliott Dunlap Smith, Provost at the Carnegie Institute of Technology, who conceived the idea of the Conference, was Chairman of the meeting; Thomas K. Sherwood, Dean of Engineering, M. I. T., served on the planning committee; and B. Richard Teare, Head of the Department of Electrical Engineering at Carnegie, was a speaker on the program.

Second International Conference on Soil Mechanics and Foundation Engineering

The Second International Conference on Soil Mechanics and Foundation Engineering will be held in Rotterdam, Holland, in June 1948. This meeting, sponsored by the Netherlands Government, is a resumption of the series initiated at Harvard University in 1936 and interrupted by the war. The president of the Conference is Karl Terzaghi, Consulting Engineer and Professor of Engineering Practice at Harvard University. The Conference is being organized by J. P. Van Bruggen, Director of Public Works, Rotterdam, T. K. Huizinga, Director of the Laboratory of Soil Mechanics in Delft, and other Dutch engineers. The Conference will be conducted in the English language.

In the United States, a National Committee on Soil Mechanics, consisting of thirty-five outstanding foundation engineers and soil mechanics experts representing professional engineering societies and governmental engineering organizations, has been formed. Philip C. Rutledge, Professor of Civil Engineering at Northwestern University, is chairman of the Committee. Its official address is: U. S. National Committee on Soil Mechanics, The Technological Institute, Northwestern University, Evanston, Illinois. To insure adequate representation of the United States in the technical works of the Conference, the National Committee has been divided into fifteen subcommitees covering the major technical subdivisions of Soil Mechanics and Foundation Engineering.

Prospective members of the Conference and authors of papers are requested to notify the National Committee of their intentions as soon as possible. To meet the conditions set up by the Dutch organizing committee, authors of papers to be published in the first volume of Proceedings of the Conference must submit in triplicate to the National Committee a title and brief (250 word) description of each paper prior to September 1, 1947. For this volume completed papers must be received by the National Committee by December 1, 1947.

Organized travel for those attending the Conference is planned and will be arranged by the National Committee. Complete information on the Conference can be obtained by writing to the U. S. National Committee on Soil Mechanics.

New Members

ALLERDING, JOHANNA E., Librarian, University of California, Los Angeles, Calif. L. M. K. Boelter, W. L. Orr.

ALVORD, HERBERT H., Instructor in Mechanical Engineering, University of Michigan, Ann Arbor, Mich. F. L. Schwartz, H. E. Keeler.

ARNOW, LEONARD, Instructor in Engineering Drawing, New York University, New York City. Irwin Wladaver, L. O. Johnson.

BELL, LAWRANCE F., Instructor in Industrial Engineering, Stanford University, Stanford, Calif. C. H. Oglesby, E. L. Grant.

BLAKE, COLIN D., Instructor in Mechanical Drawing, Louisiana State University, Baton Rouge, La. L. J. Lassalle, L. L. Cooper.

BLANCHE, JOHN G., Assistant Professor of Mechanical Engineering, Louisiana State University, Baton Rouge, La. F. T. Carroll, G. F. Matthes.

BOLT, JAY A., Associate Professor of Mechanical Engineering, University of Michigan, Ann Arbor, Mich. F. L. Schwartz, R. S. Hawley.

BURDICK, GERALD F., Assistant Professor of Industrial Mechanics, Alfred University, Alfred, N. Y. C. W. Merritt, R. M. Campbell.

CAMPBELL, REED W., Instructor in Engineering, Grove City College, Grove City, Pa. W. C. Frishe, C. J. Headland.

CHENEA, PAUL F., Instructor in Mechanics, University of Michigan, Ann Arbor, Mich. R. A. Dodge, E. L. Eriksen.

COLBY, HOWARD R., Instructor in Mechanical Engineering, University of Michigan, Ann Arbor, Mich. F. L. Schwartz, H. E. Keeler.

COLE, ROBERT C., Associate Professor of Drawing, University of Michigan, Ann Arbor, Mich. F. L. Schwartz, F. R. Finch.

CONNER, JOHNSON S., Assistant Professor of Mechanical Drawing, Louisiana State University, Baton Rouge, La. L. J. Lassalle, L. L. Cooper.

DESSAUER, WALTER E., Assistant Professor of Drawing, Tulane University, New Orleans, La. G. W. Stephenson, A. M. Hill.

EDMONSON, GLENN V., Associate Professor of Mechanical Engineering, University of Michigan, Ann Arbor, Mich. F. L. Schwartz, H. E. Keeler.

EVANS, EDWARD E., Instructor in Civil Engineering, Louisiana State University, Baton Rouge, La. W. P. Wallace, A. B. Bronwell.

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